THE OCTOBER SCIENTIFIC MONTHLY

Edited by

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NEW BOOKS OF SCIENTIFIC INTEREST

Physical Science. W. F. EHRET, ed. Illustrated. x + 639 pp. $3.90. June, 1942. Macmillan.

The purpose of this book is not to train specialists but to provide a general background of knowledge of the physical sciences. The basic concepts of astronomy, chemistry, geology and physics and their interrelationships are discussed.

Molecular Films, The Cyclotron and the New Biology. H. S. TAYLOR, E. O. LAWRENCE and I. LANGMUIR. Illustrated. 112 pp. $1.25. 1942. Rutgers.

Two Nobel Prize winners and an American member of the Pontifical Academy of Science contribute essays on Fundamental Science from Phlogiston to Cyclotron, Molecular Films in Chemistry and Biology, and Nuclear Physics and Biology.

The Stone That Burns. W. HAYNES. Illustrated. xii + 345 pp. $3.75. August, 1942. Van Nostrand.

This story of the American sulphur industry tells how American ingenuity has enabled this country to become self-sufficient in its needs for sulphur. Statistical tables on production, consumption, distribution, etc. of sulphur are contained in the appendix.

On Growth and Form. D. W. THOMPSON. Illustrated. 1116 pp. $12.50. August, 1942. Macmillan (Cambridge).

This volume covers biological problems of growth and form, and form and function, in their relation to physical principles and mathematical laws. The physics and mathematics used are elementary, but advanced enough to throw light on fundamental biological problems.

The Invertebrate Eye. G. L. WALLS. Illustrated. xiv + 785 pp. $6.50. August, 1942. Cranbrook Institute of Science.

The invertebrate eye and its adaptive radiation are discussed in three main sections: the fundamental background information, the environmental reasons for evolutionary changes, and the history of the eye traced from the lowest living vertebrates to the highest.

The Biological Action of the Vitamins. E. A. EVANS, JR., ed. Illustrated. ix + 227 pp. $3.00. July, 1942. Chicago.

This symposium includes papers on the biological action of vitamins, clinical aspects of vitamin B_1, pellagra and its treatment with nicotinic acid, pantothenic acid in human nutrition and the economy of phosphorus in the animal organism.

Microbiology and Man. J. BIRKELAND. Illustrated. x + 478 pp. $4.00. August, 1942. Crofts.

This elementary textbook is an account of the diverse properties and characteristics of microorganisms, a description of the various tools and techniques for their handling, and an inquiry into their subtle relationships to everyday life.

The Seashore Parade. M. L. GUBERLET. Illustrated. 197 pp. $1.75. 1942. Jaques Cattell.

The common animals of the seashore—plankton, sponge, jellyfish, starfish, worms, clams, snails, sea angels, devil fish, crabs, shrimps and tunicates—are all described in simple terms for children or anyone who is interested in seashore life. Colored drawings and pen sketches illustrate the text.

Adventures with a Microscope. R. HEADSTROM. Illustrated. xxiv + 232 pp. $2.00. 1941. Stokes.

Fifty-nine simple experiments, most of which are in biology, for boys and girls interested in science to carry out with a microscope are described in this book. The reader is told how to find the material, how to study it, what he will see and what it means.

War Medicine. W. S. PUGH, ed. Illustrated. 565 pp. $7.50. August, 1942. Philosophical Library.

This symposium is divided into three parts: Surgery, Aviation and Naval Medicine, and General Medicine. The fifty-seven chapters cover the treatment of most of the problems which confront the military doctor—from chigger bits to gunshot and stab wounds.

Nutrition and the War. G. BOURNE. 2nd ed. xii + 148 pp. $1.50. July, 1942. Macmillan (Cambridge).

Dr. Bourne has the English housewife in mind in writing this book of information on foodstuffs, the principles of dietetics, and vitamins. Various foods and their relative values, nature and composition are presented in table form at the end of the book.

Psychotherapy in Medical Practice. M. LEVINE. xiv + 320 pp. $3.50. 1942. Macmillan.

This is a non-technical handbook in psychotherapy intended for the general practitioner, the medical specialist in fields other than psychiatry and the medical student. It is intended to satisfy the needs of the non-psychiatrist who finds a daily use for psychiatric understanding and facility.

Nobel Prize Winners: Charts—Indexes—Sketches. Compiled by F. KAPLAN. Illustrated. xiv + 144 pp. $2.50. 1941. Nobelle.

This volume represents the second and revised edition of a biographical history of the Nobel Prize winners. It includes an Alphabetical Index, a Chronological Chart, a Nationality Chart and Biographical sketches for each of the five types of awards.

The Dictionary of Philosophy. Ed. by D. D. RUNES. 343 pp. 1942. Philosophical Library.

The aim of this dictionary is to provide teachers, students and laymen interested in philosophy with correct definitions and descriptions of the philosophical terms throughout the range of philosophical thought. In the volume are represented all the branches as well as schools of ancient, medieval and modern philosophy.

THE SCIENTIFIC MONTHLY

OCTOBER, 1942

RECENT ADVANCES IN OUR KNOWLEDGE OF THE PHOTOGRAPHIC PROCESS

By Dr. C. E. KENNETH MEES

DIRECTOR OF THE RESEARCH LABORATORY AND VICE-PRESIDENT, EASTMAN KODAK COMPANY

WHILE many materials are sensitive to light and can be used for making photographs, the present art of photography is based upon one specific process: The light-sensitive material is silver bromide in the form of extremely small crystals held in a layer of gelatin. These crystals are very sensitive to light when the reaction to light is made manifest by the process of development; that is, by the treatment of the exposed material with a solution of a suitable reducing agent. After exposure to light, the crystals are very much more easily reduced to metallic silver than before they have been exposed, and as a result of this difference, the effect of exposure becomes visible as an image composed of metallic silver.

The direction in which advances have been made in recent years is in the elucidation of the structure of the light-sensitive materials and the factors which produce great sensitivity in the silver bromide crystals, so that very small amounts of light are sufficient to make them developable; in the study of the action of light itself and of the change which occurs in the exposed crystals, and in the study of the development reaction by which the exposed crystals are reduced to metallic silver.

The nature of the silver halide crystals and the origin of their sensitivity were elucidated between 1920 and 1930. An adequate theory of the nature of the reaction of light has only become available in the last three or four years, and our views as to the nature of the development reaction have changed very radically in the last year or two.

A photomicrograph of the silver halide crystals of the light-sensitive emulsion is shown in Fig. 1. These silver halide crystals are composed of silver bromide containing a small amount of silver iodide, and they may be dyed to sensitize them to the longer wave-lengths of light. The crystals vary considerably in size but are of the same general shape. They are triangles and hexagons, which are the natural forms of silver bromide, and they are held in photographic gelatin. When they are exposed to light, the silver halide crystals are affected in some way by an extraordinarily small amount of light, as a result of which they become developable.

About twenty years ago, an attack was made on the origin of the sensitivity of the silver bromide crystals by three groups of investigators—Svedberg and his collaborators in Sweden, the British Photographic Research Association in

England and our laboratories in Rochester. Soon after gelatin emulsions were first made, it was found that the exposure required in the camera was greatly lessened if the emulsion had been cooked for some time at a high temperature or if it had been treated with ammonia. It was observed that the grains had grown larger during this treatment, and it was concluded that their greater sensitivity was due to their greater size. This is true, but it is by no means the whole story! For a long time, it had been known that if an emulsion were treated with some chemicals, such as chromic acid, it lost its sensitivity, even though the size of the grains was not changed. Also, sensitivity depends very much upon the particular kind of gelatin used in making the emulsion. Some gelatins easily give very sensitive emulsions, while others, even with prolonged cooking, will not give good sensitivity. This problem has been studied by emulsion makers ever since gelatin emulsions have been made, but no clue was found until Dr. S. E. Sheppard studied systematically the various fractions obtained at each stage in the preparation of photographic gelatin.

Photographic gelatin is made from clippings from the skins of calves. For this purpose, the skin of the face and ears is used because these parts are of no value for leather. These clippings are first washed and then treated with lime for a long time to remove the fat and hair. The lime is removed by long washing with weak acid and then with water. Then the material is cooked in steam kettles until the gelatin is extracted, and the extract is concentrated if necessary and allowed to set to a jelly; the blocks of jelly are cut into thin slices

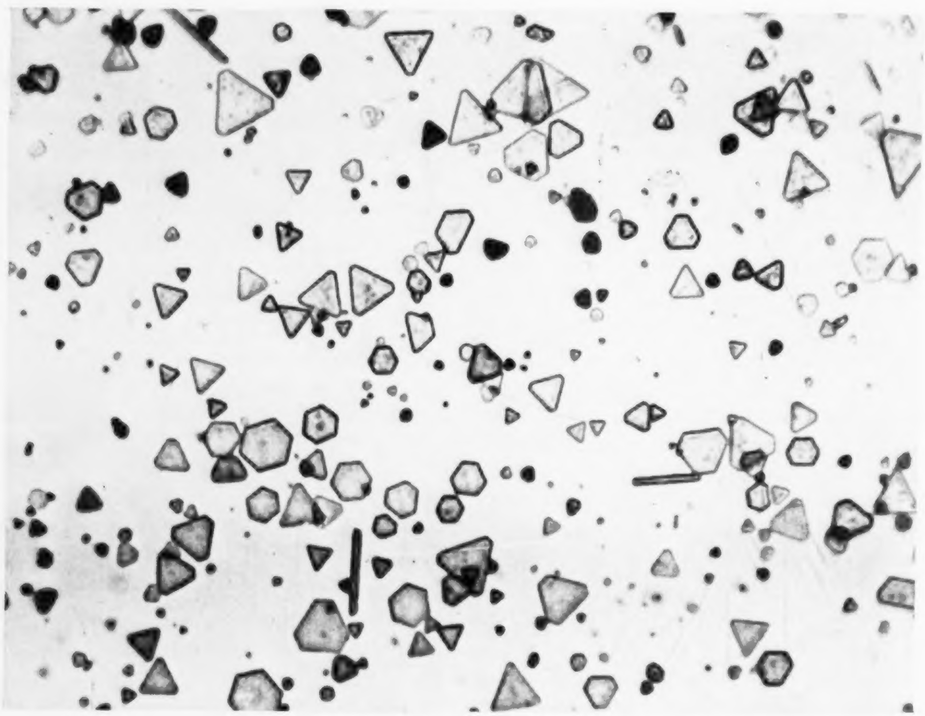

FIG. 1. PHOTOMICROGRAPH OF SILVER HALIDE CRYSTALS. ×2500
OF A NEGATIVE EMULSION. THESE SILVER HALIDE CRYSTALS ARE COMPOSED OF SILVER BROMIDE CONTAINING A SMALL AMOUNT OF SILVER IODIDE.

and stretched out on nets to dry. Sheppard found that in the acid liquors in which the limed clippings had been washed there seemed to be a concentration of some sort of sensitizer. When this liquor was added to a gelatin which did not give sensitivity, it at once increased the sensitivity of the emulsion. From the acid liquor, he extracted a very small quantity of a fatty substance, but when this substance was identified as cholesterol and prepared in a pure state, it had no sensitizing power; the sensitizer was merely associated with it as a slight impurity. However, the fact that sterols can be obtained from the seeds of plants led to examination of extracts of those seeds, and some of them were found to sensitize, the most effective being mustard seed. This led to the identification of the sensitizing substance in gelatin as being mustard oil, which contains sulfur. Presumably, the animals obtain the oil from the plants they eat, so that the amount present depends upon the pasturage they have had.

When mustard oil is treated with alkali, it forms allyl thiocarbamide. If silver bromide is treated with a solution of allyl thiocarbamide, the surface of the silver bromide is attacked and grows a mass of white needles containing both allyl thiocarbamide and silver bromide. When these are treated with alkali, they break down into little black spots which must consist of silver sulfide because of the chemistry of the reaction.

When the development of grains is observed under the microscope, it starts from specks, these increasing in number and size until each grain is transformed into metallic silver. The question arises as to whether these centers of development existed before exposure or came into existence when development started. Sheppard's work put the whole matter beyond doubt. Sensitivity depends upon the existence of specks far too small to be seen in the microscope, and these specks consist of silver sulfide, probably

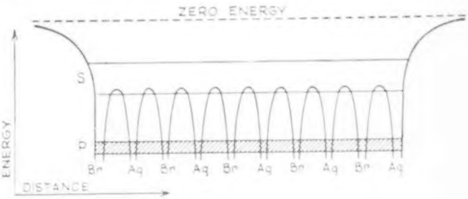

FIG. 2. ENERGY DIAGRAM
OF A SILVER BROMIDE CRYSTAL.

derived from the mustard oil in the gelatin. The amount of mustard oil in an emulsion is very small. A ton of emulsion contains only a couple of drops, and the evidence for the existence of the sulfide specks is therefore indirect.

It has already been stated that when a film is exposed to light, an invisible image is produced in the emulsion. To understand how this image is formed, we must know how the sensitizing specks act during exposure and what the light does to the silver bromide.

When Sheppard found that the sensitizing specks consisted of silver sulfide, he and his colleagues advanced a theory of the action of light which they called the "concentration speck theory." The silver sulfide specks, they suggested, are formed on the surface of the silver bromide crystal and must in some way enter into the lattice of atoms of which the crystal is composed. They produce strains in the crystal, therefore, and these strains stretch into the surface of the crystal as an area of weakness. When light falls on such a crystal, energy travels through the crystal until it reaches the boundary of the speck. At this boundary, owing to the sudden change in structure, metallic silver is set free from the silver bromide. The sensitizing speck thus acts as a nucleus for collecting or concentrating the energy throughout the whole area of the crystal and for liberating metallic silver at the speck itself.

There was still wanting a mechanism for the operation of this concentration speck theory. Such a mechanism has

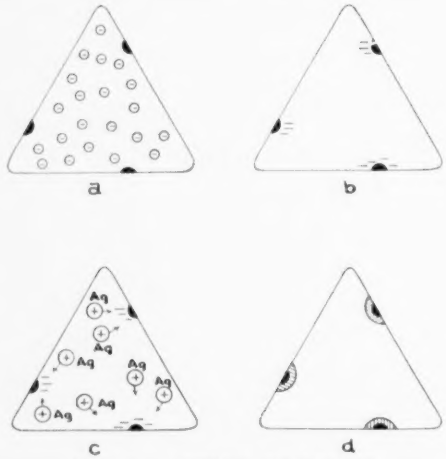

FIG. 3. ACTION OF LIGHT UPON A SILVER BROMIDE CRYSTAL. (A) LIBERATION OF ELECTRONS INTO THE CONDUCTING LEVEL. (B) CHARGING OF THE SENSITIVITY SPECKS BY THE LIBERATED ELECTRONS. (C) MIGRATION OF SILVER IONS TO THE CHARGED SPECKS. (D) DEPOSITION OF SILVER ON THE SPECKS TO FORM THE LATENT IMAGE.

been supplied by the work of Professors Gurney and Mott and of Dr. J. H. Webb. In the first place, if we consider the energy diagram of a silver bromide crystal as a whole (Fig. 2), there are two energy levels of importance in the photographic process, the *S* and *P* levels, in which the electrons may be situated. The *S* band is normally empty and is referred to as a "conduction band." The *P* band is normally completely filled with electrons. Upon exposure of a silver bromide crystal to light which is absorbed in the long wave-length end of the characteristic absorption band, the electrons are transferred from the lower *P* band to the *S* band, and the crystal becomes conducting. This property is well known in other materials, as well as in silver bromide, as "photo-conductance," and the silver bromide crystal exposed to light may be imagined to be filled with a sort of gas of conducting electrons. This is the primary photographic process—the thing that happens instantly when light falls on the crystal (Fig. 3). When the electrons set free in this way reach a sensitivity speck, either consisting of an impurity or of the silver sulfide derived from the gelatin, the electrons will be trapped and the sensitivity speck will become negatively charged by the electrons that it has absorbed.

In a crystal there are always available silver ions in the silver bromide lattice, and these silver ions will travel through the crystal until they reach a sensitivity speck, and there the charge on the ion will be neutralized by the negative charge on a trapped electron and the silver atom freed by the discharge of the ion will be deposited at the sensitivity speck, so that the electrons set free into the conductivity level by the original exposure to light are eventually transformed into silver atoms deposited on a sensitivity speck. This theory postulates that the production of an image by the action of light occurs in two stages: first, the release of free electrons which occurs instantaneously, and then the transfer of the free electrons by neutralization through the silver ions into silver atoms at the sensitivity specks.

This theory of Gurney and Mott supplies a mechanism for the phenomenon known in photography as the "failure of the reciprocity law." Bunsen and Roscoe found that for the photochemical production of hydrochloric acid time and intensity were reciprocal. That is, the production of hydrochloric acid was independent of the rate at which light energy was supplied and was dependent only on the total amount of energy. In the case of photography, however, it is well known that the effect of light is not independent of the rate at which it is supplied. There is an optimum rate for the formation of the maximum amount of photographic image, a rate corresponding to an exposure of a small fraction of a second. If the exposure is much greater than this—an hour, for instance, considerably more energy—two or three times more—may be required to produce the same density of deposit. On the other hand, if the exposure is much

shorter—a ten-thousandth or hundred-thousandth of a second, for example, somewhat more energy will be required. In order to account for the inefficiency of very low intensities of light in producing an image, it must be assumed that the silver atoms formed at the sensitivity specks can easily be lost in the early stages of the formation of the image by acquiring a positive charge owing to thermal action. Thus, for instance, newly liberated silver atoms would be more easily lost than those which have entered a silver crystal lattice to form metallic silver.

On the other hand, with high intensities of light the electrons are supplied too rapidly, the silver ions do not have time to reach the sensitivity specks by diffusion through the crystal, and some of the electrons are repelled from the highly charged sensitivity specks before they can be neutralized. Much light has been thrown on the nature of the reciprocity failure by a study of the formation of the image at different temperatures.

The metallic silver deposited at the sensitivity speck and forming a nucleus which facilitates development is what has been known in photography from the earliest days as the "latent image." There has been much discussion as to the nature of the latent image, but there is now no question that it consists of metallic silver concentrated at local points in the silver bromide crystal. If the silver bromide is exposed to large amounts of light, a visible discoloration takes place, and this undoubtedly consists of metallic silver. This can be shown by the use of the x-rays in the ordinary crystal structure analysis, when characteristic rings of silver crystals are obtained, and also by the examination of the image by means of the electron microscope, when it can be seen to consist of crystals of silver. Inasmuch as the visible image

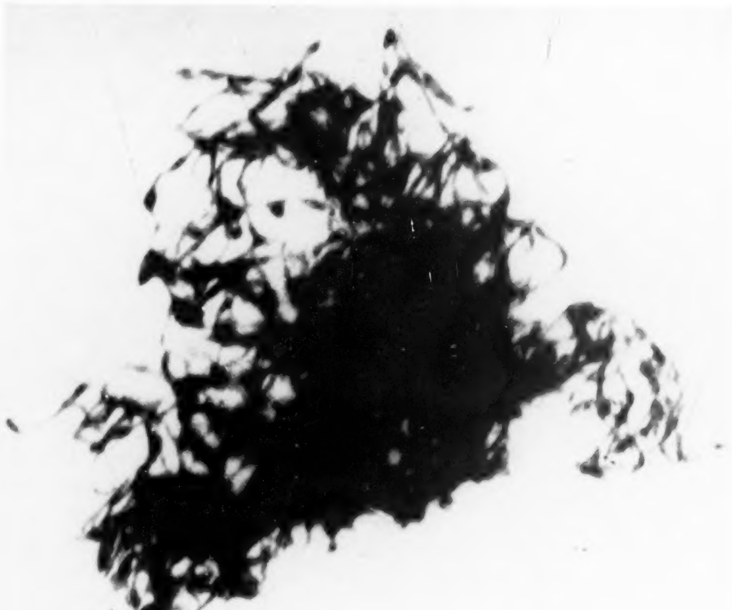

FIG. 4. ELECTRON MICROGRAPH OF A GRAIN OF DEVELOPED SILVER. $\times$ 50,000.

produced by long exposure to light consists certainly of metallic silver, the latent image produced by short exposure is almost certainly of the same nature.

The mechanism of photographic development has always been very obscure. The general theories as to the nature of development until quite recently were those which conceived it as being similar to crystallization from a supersaturated solution of metallic silver. In the absence of nuclei deposition of silver would be delayed, and this would check further solution of the silver bromide. In the presence of a latent image nucleus, deposition of silver is facilitated and the solution, reduction and deposition of the silver bromide continues until the crystal is converted into metallic silver. There are many physico-chemical difficulties in this mechanism, but it would undoubtedly have continued as a possible explanation of development had it not been for the evidence recently supplied by the electron microscope as to the form of the silver produced in development.

The silver grains of the developed image are very small and the microscope is unable to distinguish any appreciable

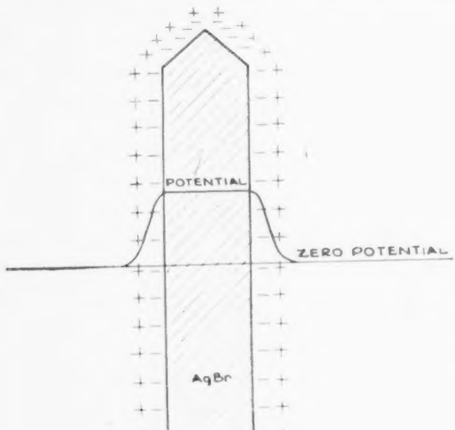

FIG. 5. DISTRIBUTION DIAGRAM OF THE POTENTIAL AND CHARGE OF A SILVER BROMIDE CRYSTAL.

structure in them, so that in spite of some suggestions that the silver might be formed as filaments, the general view was that the developed silver grain was a spongy mass of silver crystals somewhat resembling a lump of coke. When developed silver was examined with the electron microscope, however, it was at once seen that the silver grain is a tangled mass of ribbon-like filaments looking very much like a mass of seaweed (Fig. 4). This is not only very important for the light that it throws on the actual structure of the developed image, but it at once becomes necessary to account for the formation of such an unusual form of silver in the development of the silver bromide. Clearly, the supersaturation theory of development will not do at all. It might be thought that the filaments are formed in cracks in the crystal, but this was disposed of by an examination of the very small crystals of so-called "Lippmann emulsions," crystals too small to be seen in a microscope. With the electron microscope, these appear as normal silver bromide crystals, but when they are developed, each of them turns into a single filament of silver, these filaments being much longer than the diameter of the crystal from which they were formed. The impression therefore becomes overwhelming that the silver filament is formed by ejection from the silver bromide crystal. It is squirted out during the process of development from the solid crystal, and the picture we form of the development reaction is that the reducing ions of the developing agent attack the silver bromide crystal, and in some way the initiation of tre formation of metallic silver is facilitated by the presence of the latent image speck.

The mechanism for this is supplied if we consider the potential at the surface of the silver bromide. The surface of the silver bromide grain itself has an excess of bromide ions, which give rise to a negatively charged surface. How-

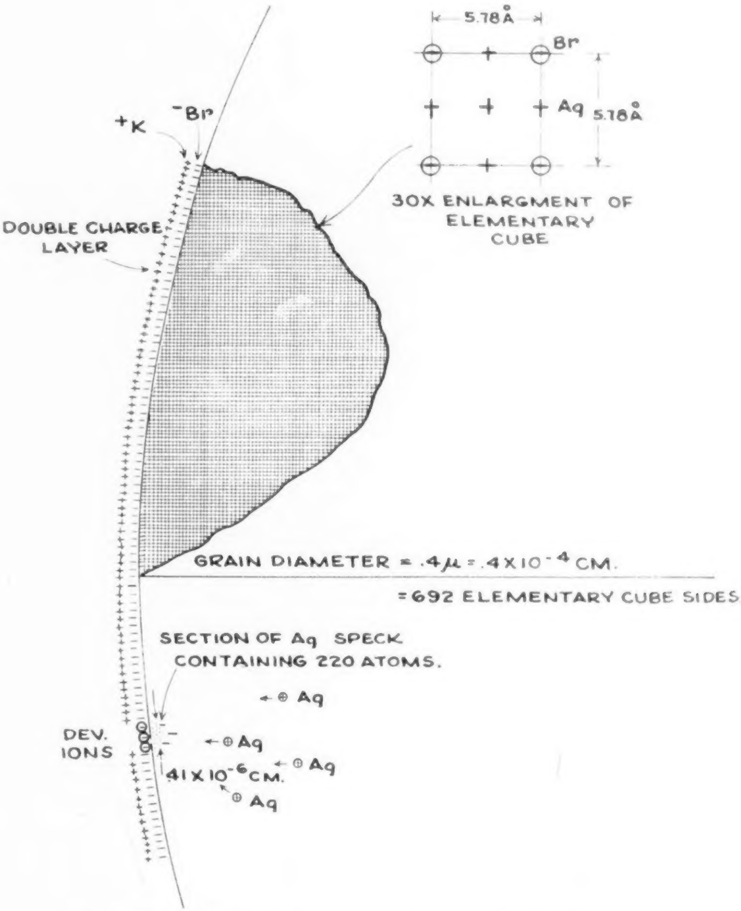

FIG. 6. DIAGRAM SHOWING A LATENT IMAGE SPECK
IN A SILVER BROMIDE CRYSTAL ATTACKED BY A DEVELOPER.

ever, just outside this negative charge, a positive layer of potassium ions must be present to neutralize the negative charge. Without such a neutralizing layer of positive ions, it would be impossible for the surface of the silver bromide grain to be covered with negative bromide ions, since the amount of such a charge in so small a region would give rise to explosive forces. A double charge layer, consisting of negative bromine ions on the grain and positive potassium ions in the gelatin just outside, may be considered to exist around the surface of each silver bromide grain (Fig. 5). Grains with such a double layer (in a solution) would move under an electric field as negatively charged bodies, since the negatively charged grain would be forced in one direction by the field, and the surrounding movable positive-ion layer in the opposite direction; but since at any point in the liquid there would be positive ions to form the surrounding positive shell, the double charge layer would be maintained. That the surface charges on the particles and surrounding charge layers do neutralize each other in the manner outlined is proved by the fact that the colloidal suspension does not possess a net charge of either sign but is neutral as a whole.

It may be assumed that a grain, owing to its double charge layer, behaves toward outside charges and also those located inside the grain as a neutral body. An electron placed inside such a double charge layer would experience no force nor, in the same way, would an electron placed outside such a double layer. However, there is a marked difference in potential between the inside and outside of the grain, and the total jump in this potential occurs in the region between the two charge layers. The potential gradient between these charge layers accordingly gives rise to a strong electrical force between the layers, and an electron placed between them would experience a force toward the outside. It is considered that the double charge layer acts in this way as an effective potential barrier to the entrance of an electron into the silver bromide grain of the emulsion and prevents the developer from attacking the grain.

The conditions existing in the exposed grain containing a latent-image silver speck may be seen in Fig. 6. This shows a greatly enlarged scale model of a charged grain surface with a clump of silver atoms on the surface which is supposed to represent the latent image produced by exposure to light. The clump shown includes 220 atoms, with approximately the correct spacing. This size was chosen as representing a fair mean of the values given by various workers.

J. H. Webb assumes that development of a grain is initiated by the break in the double charge layer caused by the silver speck, permitting the negative developer ions to reach this silver speck. The latent-image speck is viewed as an electrode penetrating into the grain. The tendency on the part of the developer ions to release electrons to the silver causes electrons to pass to the electrode and charge it negatively. As explained by Gurney and Mott, this occurs if the electrons of the developer ions are situated in levels above the highest occupied energy levels of the silver metal. The penetration of this negative electrode into the silver bromide grain upsets the neutral electrical condition previously existing in the grain, and there arises an attractive force for the positively charged silver ions in the neighborhood of the latent-image speck. Positive silver ions always exist in the crystal lattice owing to temperature motion, and these diffuse to the speck under the attraction of the negative charge there and enlarge the silver speck. Thus, it is supposed that the original silver speck of the latent image continues to grow by this mechanism. As this proceeds, the protective double layer is more and more ruptured, and a rapidly increasing area of the silver halide grain is exposed to the attack of the developer. Since the reduction of silver bromide by a developer is exothermic, considerable amounts of energy are liberated at the boundary between the silver and the silver bromide, while the local rise in temperature facilitates the migration of silver ions, so that the metallic silver is extruded as a filament.

The process of development itself involves certain requirements as to absorption and catalysis of the development reaction, which explain why one substance is a developer and another reducing agent having approximately the same reduction potential is not a developer. Much work remains to be done on the chemical reactions involved in development, but the knowledge which has recently become available as to the formation and nature of the latent image and its function in promoting the development of the silver halide grain has enabled us to form a much clearer picture of the phenomena of the photographic process than was possible previously.

AGRICULTURAL PRACTICES IN SEMI-ARID NORTH CHINA

By Dr. RAYMOND T. MOYER

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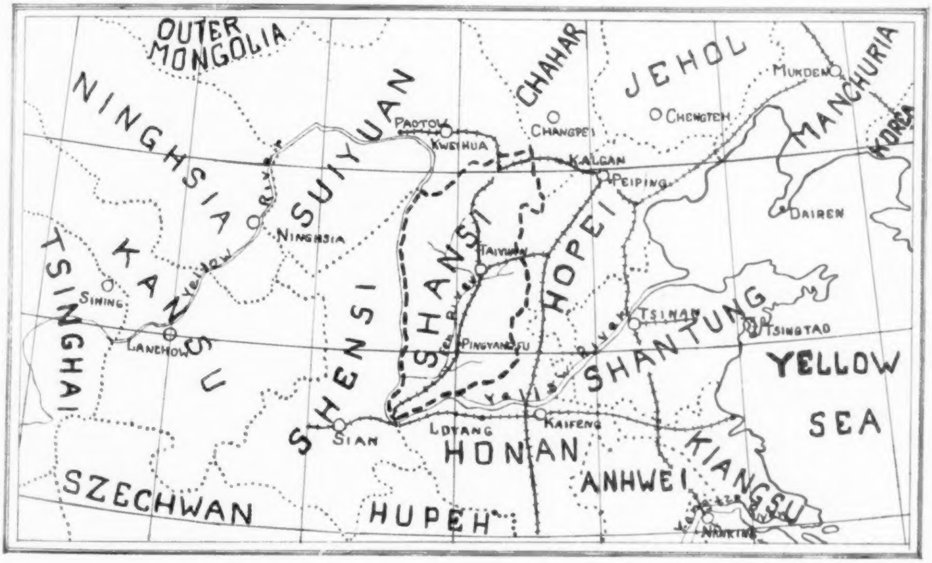
WHILE a good deal has been written concerning agricultural practices in China, most of the existing accounts have had to do with the rice farmers in the canalized regions of the Yangtze delta or with the sturdy plodders on the overcrowded Shantung plain. Much less has been told about farming as it is done in China's semi-arid area, where moisture is the most important limiting factor in production, where one crop per year, not two or three, is the rule, and where the results of erosion stand out so strikingly.

Such are conditions in Shansi, a province just west of the mountains that form an abrupt inland border to the North China plain. Important in Chinese history as one of the first areas to be occupied by the forebears of the present Chinese people, Shansi has latterly received attention because of the immense coal reserves that exist there, and because its mountainous topography and



MAP OF SHANSI AND SURROUNDING AREAS

Between the sub-humid provinces to the east and the arid areas to the far northwest lies Shansi Province, the most typical representative of China's semi-arid region. Shansi is often considered a key to the military control of North China. Other reasons for the current interest in this province are the fact that a considerable amount of cotton is produced on its southwestern plains and that, according to an estimate of the National Geological Survey, it possesses more than half of China's entire coal resources. It has been inhabited since the beginnings of Chinese history; it was the birthplace of the military hero, Kuan Ti, who is now widely worshiped as the God of War; and its business men, during the last dynasty, carried on trade from Kwangtung to Mongolia, eventually to become the nation's largest bankers. To a greater extent even than most provinces in China, agriculture is Shansi's present most important pursuit.

TRAVELER GAZING ON THE GRANDEUR OF THE MOUNTAINS OF SHANSI
Shansi's high altitudes and clear atmosphere remind one of Colorado and Wyoming. Winters at this latitude, which is about that of Richmond, Virginia, are colder than at Cheyenne, Wyoming. However, snowfall is not common, since between 80 and 90 per cent. of the annual precipitation of 16 inches falls during the six months of the growing season.

strategic location make it an important key to the military control of North China. For these reasons it will continue to feature prominently in news from that part of the world.

Lying between the sub-humid provinces to the east and the more nearly arid ones to the west, Shansi represents, better than any other province, the large areas of China's north and northwest which may be designated as semi-arid. The average precipitation of about one third of its total area does not exceed 14 inches per year. In one small section it is as high as 21 inches. The central part of the province, which represents average conditions, receives about 16 inches.

However, with 80 to 90 per cent. of this total precipitation falling within the six months of the growing season, and between 50 and 60 per cent. during the important months of July and August, better crops are often harvested than would normally be expected with so low a total fall. The unfavorable factor in the rainfall situation is an unevenness in the annual supply. Years of a normal fall are interspersed with an occasional year of drought, accompanied by a partial or complete crop failure.

The land surface of this region is about two thirds made up of treeless rock-surfaced mountains, bare of tillable soil except for patches along the sides and in the bottoms of wider valleys. The remaining one third consists of level alluvial plains and of low-lying loess and red soil hills. It is estimated that between 20 and 25 per cent. of the total area is tillable.

With an area of 66,256 square miles and a population estimated, before the war, to be about 12,000,000, Shansi has an average density of about 181 persons per square mile. Kansas, in 1930, had 22.9, Colorado 10.0 and Wyoming 2.3. The size of the farm, therefore, must inevitably be small. Partially irrigated farms have, on the average, between 4 and 6 acres per farm. Dry-land farms on terraced hillsides average between 9 and 15 acres.

The point of particular interest in the agriculture of this region is the accomplishment of its farmers as represented by the successful way with

which they have met the combined problems of so dense a population, a restricted amount of available land and a limited rainfall. With environmental conditions no more favorable than are those of the region occupied by Kansas, Nebraska, Colorado and Wyoming, there has been maintained in Shansi, largely by agriculture, a population which is fourteen-and-a-half times as dense as the average density of the population of these states. In spite of forty centuries of cultivation, soils remain fertile.

Since, under the influence of scientific investigation and social and economic change, the old systems and methods of farming may soon be radically altered, it would seem worthwhile, before this occurs, to record the practices that have helped to make possible these accomplishments of the past.

Considering, first, the soils, it is to be noted that not all are in a state of high fertility. There are alkali spots and areas of unproductive sands. Even on the better soils of the plains there may

THE PEOPLE OF NORTH CHINA

TOP: *left:* A potter using the potter's wheel of ancient standing, still used to make roof tiles. Tiles are first molded on the wheel into a hollow cylinder, which is then cut in two to form half-round tiles ready for the kiln. MIDDLE: *upper:* Little hope remains for these victims of famine. After two years of drought, they are now trying to continue existence on a diet of leaves, roots and weed seeds. So weak have they already become that when the writer accidentally brushed against the younger he fell weakly to the ground. MIDDLE: *lower:* A mountain farmer carrying brushwood, a cheap fuel. However, cutting brushwood robs hills of a cover needed to keep soil in place and to build up the surface of slopes so that a forest might grow there again. *Right:* The owners of the two prize-winning vegetables, leek and kohlrabi, proudly show their exhibits. BOTTOM: *left:* These shepherds, with their sheepskin coats and fur hats, are well-equipped for the cold winter temperatures which often go below zero. *Right:* These farmers are leaving for their orchards with an agricultural extension man who will teach them how to spray properly.

occasionally be seen fields that exhibit symptoms of nutrient deficiencies, particularly the yellowish-green color that accompanies a deficiency of nitrogen. The soils on slopes, where erosion has been active, are definitely low in fertility.

Nevertheless, soils of the plains, where cultivation has been practiced the longest, are on the whole fertile. Yields of wheat, on well-managed irrigated fields, are commonly between 30 and 35 bushels per acre and may reach 60. And the addition of essential nutrient elements, as has been found in numerous experiments, brings about only moderate increases in yield.

This fertility, after so long a period of cultivation, is due to several causes. Soils are deep and of a texture which favors the absorption and retention of moisture. Like the unleached soils of most semi-arid areas, they contain a natural abundance of most of the essen-

TYPICAL SCENES ON THE SHANSI LANDSCAPE

TOP: *left:* A cotton grower takes his crop to market without benefit of modern transportation. After picking, cotton is ginned locally. To transport his crop to the market, this farmer is using a typical birch carrying-pole. By the same method, hundred-pound loads of fruit are frequently taken as far as twenty-five miles in one day. *Right:* Soil eroded from surrounding hills has nearly buried this pear orchard. Many pears are raised on the terraces of this loess basin, but trees are sometimes in danger of being buried by soil washed down from the bordering cliffs and slopes. Farmers prevent this catastrophe by digging away the soil that has accumulated. BOTTOM: *left:* Sheep, when at the home, are kept in small corrals in the courtyard. Since individual flocks of sheep are seldom larger than the one kept by this farmer, sheep owners of a village find it profitable to cooperate in employing a single shepherd, who calls in the morning for his wards and returns them safely at night. *Right:* "Sunken roads," a much-discussed feature of the landscape, are formed by a process akin to gulleying, when they lie over deep soil materials. Winter winds and summer rains remove particles loosened by passing carts and animals. After many years, this lowers the road until it is often many feet below the surrounding country.

TERRACING AS A MEANS OF EROSION CONTROL

The soil patches on this hillside are very likely the remaining part of what was once a larger area of soil. Although much may already have been lost by erosion, the loss would have been much greater had these terraces not been constructed. The countless number of terraces throughout Northwest China represent an amount of labor almost beyond imagination.

tial nutrient elements. There is, moreover, a more or less regular addition of new material brought about by alluvial and wind deposition. While undoubtedly important, the application of fertilizers is to be considered as only one of the factors responsible for their continuing productiveness.

The attempts of Chinese farmers to increase the amount of land available for tillage have now become largely a matter of history. From the plains, which historical records show were in most cases occupied first, expansion was sought on hillsides. These, it may probably be believed, were at that time partially covered with forests and, in some sites, with soil deep enough to support the growth of cultivated crops.

In such places there must have been obtained, at the beginning, a very fertile soil, rich in humus. But as the humus was gradually lost, the fertility decreased and erosion set in.

The end of the story, which can be read in the conditions of to-day, shows rocky hillsides without either forests, crops or soil. The soil hills, with their deep deposits of loess and red clays, have been badly intersected with gullies, greatly reducing the amount of tillable surface. Heavy rains now run rapidly off the exposed slopes, gather in streams and eventually collect in the major rivers. The river beds, silted up with the eroded material, are unable to accommodate the larger volume of water, and the frequency of floods is increased.

Enthusiastic supporters of an erosion control program in the United States, however, have sometimes overstated the extent to which lowlands have been damaged by rock debris washed down from exposed hillsides. Individual spots have been made desolate in this way. But valley bottoms are, in a large majority of the cases, the most productive spots in mountainous territory.

Nor has the devastation produced by all the forms of erosion combined been

as enormous as statements would sometimes lead one to think. The dense population of this province, supported by agriculture under semi-arid conditions, should alone be convincing evidence to the effect that, in spite of these losses, much good soil still remains even after four thousand years of human

TOWN SCENES ON MARKET DAY

TOP: *left:* This farmer is looking over bolts of material, trying to find cloth he can afford, while the merchant figures up on his abacus what the cost will be. *Right:* Known everywhere as the "big cart," this vehicle is the family carry-all. It hauls manure to the fields, grain to market or the womenfolk to a country fair, all with equal dependability. It is springless, and its wedge-shaped iron-rimmed wheels make rutless roads impossible. MIDDLE: *left:* A showy display of red and blue grapes for sale at wholesale rates in the market. During the height of the season several hundred baskets of this size may be sold in one day to buyers who come from many distant cities and carry back their purchases to sell at retail. *Right:* Before buying for her family, this woman is trying to find the seller who has the best price on the kind of article for which she is looking. BOTTOM: *left:* The size of the bowl of the pipe which this old codger is using could not allow a long smoke. Many men keep such pipes constantly at hand, up an ample sleeve or down the back of their necks, ready for use. *Right:* A farmer buying some rope. Rope has several essential uses on Shansi farms, but for most of the multitudinous uses that American farmers find for it this frugal farmer devises cheaper substitutes.

habitation. In the main, this region is still far from having become a "man-made desert."

A much greater loss could, of course, by now have occurred had not erosion control measures been practiced since long ago. There is hardly a more characteristic feature on Shansi's landscape than the terraced slope. Built up gradually over centuries of time, hundreds of square miles of terraced hillsides now exist, representing an immense effort to prevent the loss of good soil. In the drier less productive parts of this region, proper terraces have not been made. Slight breaks have been formed at intervals along the slope, and temporary ditches are sometimes constructed along the contours to lead off surplus water. Where precipitation is more abundant, and the land more productive, level bench terraces have usually been built. When exposed to unusually severe forces of erosion, stone-supporting walls are frequently added.

The visitor, unfamiliar with such sights, is constantly amazed at seeing small patches of terraced land hanging to a hillside, no doubt the remnant of an area once much larger though still cropped as assiduously as ever.

Such sights, however, are properly to be thought of as more than mere interesting features of the landscape. This laborious preserving and tilling of small isolated pieces of land should be considered as one of the interesting examples of how, through several thousand years of experience, this seasoned race of agriculturists has found a way to cope with the problems with which they have had to deal. Many more examples may be found in the common practices of all branches of their agriculture.

In a sheltered location at the foot of a sunny slope in central Shansi lies a small group of villages around which there flourishes an important grape industry. The vines are trellised overhead, forming a cover over the ground which extends for an area of several square miles. But had nothing been done to prevent a nearby stream from overflowing its banks during the rainy season, much of the fertile land occupied by these vineyards would long ago have been injured by the sand and gravel which would inevitably have been deposited.

To prevent this, protecting dikes have been constructed from time to time along the stream's edge. Just as often, however, deposits from the flowing water have raised the level of its bed, after which the dikes were again raised. And so it has come about that, now, water is carried aqueduct fashion on a bed which is from eight to twelve feet above the general level of the surrounding country.

Equally extraordinary is the way these farmers conserve fertilizing materials with which they are familiar. This is done with an extreme of economy scarcely conceivable to the Westerner. Night soil, which is largely wasted in Western countries, is here carefully preserved and used. Animal droppings on roads are gathered by the feebler members of a household and added to the courtyard compost heap. Animal latrines are placed at intervals along the main highways—spots well bedded with straw or kaoliang stalks where passing animals have learned to stop.

But the climax of their ingenuity is displayed in the mountains, where the scarcity of fertilizers is most felt. Here, an efficient way has been devised to save manure from the thousands of sheep that pasture there during the summer. This is achieved by the simple expedient of having them spend nights on land about to be plowed, at an agreed price. In the morning, the land owner is on hand at daybreak to plow under the added material as soon as the sheep vacate, before a hot sun has had an opportunity to

snatch away into the air any part of its valued contents.

Less striking, but of tremendous importance to a successful farming of this region, is the excellent way the crops used are suited to the conditions under which grown. Common soil and climatic adaptations are well understood: wheat and cotton are raised within their ordinary temperature limits; oats and Irish potatoes are main crops in colder regions; and kaoliang, a drought-resistant grain sorghum, is grown under suitable temperature conditions where the rainfall is less, though supplanted with maize where rainfall is more abundant.

But the crop grown nearly everywhere is one which scientific investigations in Colorado have found can produce a greater weight of plant material with a given quantity of water than can any other of the ordinary field crops. This is millet, Shansi's most important single crop.

Not only is millet of value because drought resistant; it is, in addition, extraordinarily useful. The varieties in common use produce more grain than wheat, and the stalks make a suitable fodder for work animals. From one plant, therefore, many peasants obtain their main article of diet; and the need of forage for animal feeding is so completely met by it that practically no land need be devoted to the growing of crops for hay alone.

This fact constitutes an important factor in the ability of this agriculture to provide for the present dense popula-

CROP SCENES OF THE SHANSI AREA

TOP: *left:* Virginia tobacco grows well in Shansi. The increasing popularity of the cigarette has created a heavy demand for improved tobaccos. *Middle:* An important grape growing district has hundreds of acres of vines trellised overhead in this manner. In the late summer the terraces of leafy vines on trellises are banked picturesquely against a hillside and the thickly clustered bunches of grapes hang suspended below. In the fall, the bare vines are taken down and buried in the soil, to protect them against the cold dry winds of winter. TOP: *right:* Millet is Shansi's most valuable crop. The important place given millet has a great deal to do with the ability of this semi-arid region to support so dense a population. It is among the most drought-resistant of crops; it yields more grain than wheat; and its straw provides an acceptable fodder for work animals. BOTTOM: *left:* Like many Shansi farmers, this old man prefers to plant soybeans with the kaoliang, which he is now cutting. BOTTOM: *right:* The English name for this crop, "kaoliang," comes from the Chinese words meaning "tall grain." It is a grain sorghum that is widely used because of its resistance to drought. The grain is sometimes eaten by the peasants, but it is more widely used as feed for animals. Stalks are utilized to make everything from children's toys to courtyard fences.

SHANSI FARMERS HARVESTING THEIR CROPS

TOP: *left:* Aided by scientific methods, these workers are developing new agricultural materials. Improved wheat strains are being developed with methods worked out at Cornell University. Careful tests indicate that, resulting from these efforts, farmers will soon be provided with a new variety which produces between 20 and 30 per cent. more than old varieties when grown under the same conditions. *Right:* An important interlude between periods of work in the field. Work begins at dawn for these farmers. They then return at about eight o'clock for their breakfast. At noon a long interval is taken out for dinner and rest, after which they work until dusk. This rather sensible arrangement allows them to spend a full day in the fields and still to avoid the scorching mid-day sun. MIDDLE: *left:* An ingrained sense of economy requires that peanut land be sifted for stray nuts at harvest time. Sandy soils have been found suitable not only for the growing of peanuts, but also for the hand-sifting to get out all the nuts which they believe to be profitable. *Right:* After kaoliang stalks have been felled, the precious heads are promptly removed and taken home, where there will be less danger of their being stolen. BOTTOM: *left:* Millet gruel alone may be tasteless, but when slices of this pumpkin are cooked with it, the flavor is very much improved. *Right:* A good crop of millet at the threshing-floor. When brought in from the fields, grain is stacked until things are in readiness for threshing. Before threshing, heads are removed from the stalks and spread on the floor for further drying.

tion. Without a crop of such characteristics, there would be insufficient food for so many people. But the extensive use of this crop also illustrates a principle which appears to run through a number of the farming practices. This principle may be stated to be a demand that the resources available for agricultural production shall be utilized in ways so that a maximum amount of food of types suitable for the human population will be produced.

An operation of this principle is likewise to be seen in the manner productive livestock is raised. The forms most commonly kept are sheep, poultry and swine, and the feature in their raising which is of particular note is the way they are fed. In Western countries, the diet of such animals includes large quantities of sound grain which could also serve as direct food for human beings. In China, the feeding of from four to six pounds of grain, to produce one pound of meat, loses, for the human population, too great a part of the total energy values which these substances contain. So livestock is raised principally on materials which have slight or no value for direct human use.

Chickens, accordingly, pick up a large part of their living in fields and village streets or out of grain too poor for sale. Swine are fed on the refuse of kitchens or on otherwise unsalable by-products in the making of certain foodstuffs. Sheep graze the grass of wastelands and receive supplementary feedings of plant remains such as bean stalks and sweet potato vines. It is true that the breeds of livestock which can survive on diets such as these are not models either of form or of productiveness. But they do live and produce. And, done in this way, the inclusion of animal husbandry in their system of farming results in an increase rather than in a decrease of the total amount of food made available for human use.

An examination of the ordinary farm operations reveals, as well, the following of many practices that are of unquestionable soundness.

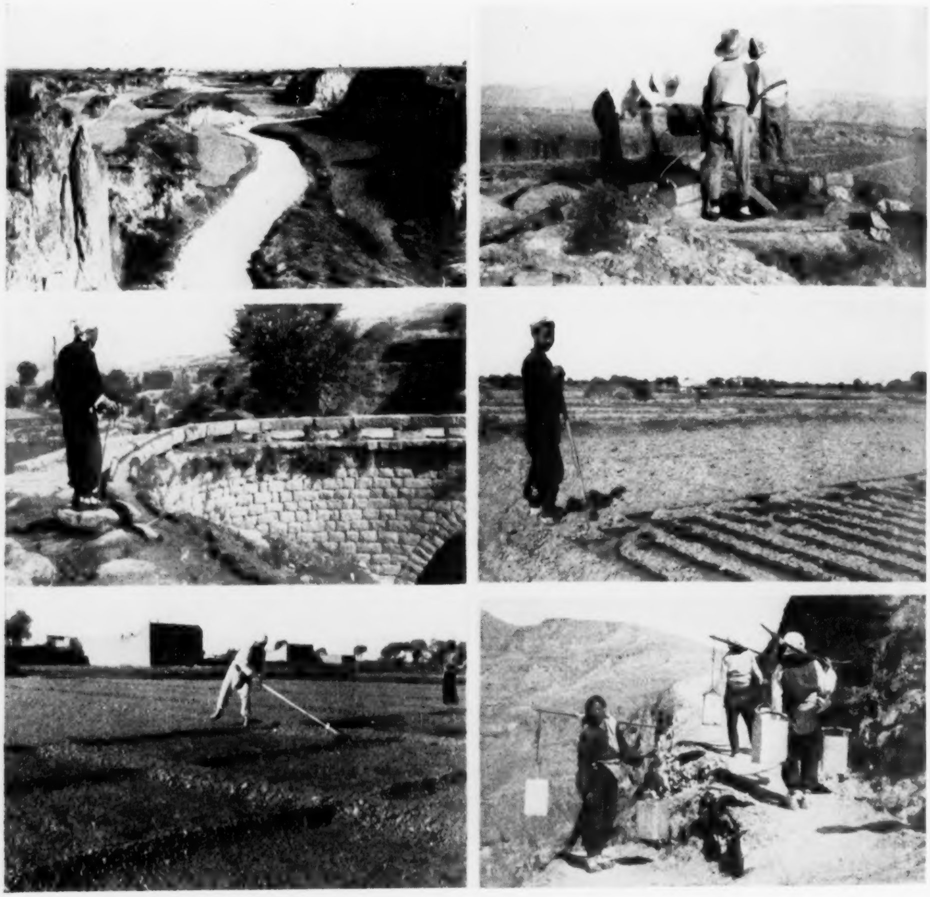
Soil investigators have, within recent years, found the reason why undecomposed organic matter applied to the soil will sometimes cause young plants to become yellow and stunted in growth. Although the cause of this injury has not been understood by Shansi farmers, they follow a practice which has been found to avoid it. This practice is to compost organic manures. All prosperous households have piles to which are added an assortment of materials collected from the countryside or produced on the farmsteads. As the time approaches to use this manure, the pile is watered and stirred at intervals, until the entire lot is well rotted. The rotted product is then applied to the soil, without danger of injury to the growing crop and with the nutrient elements in a more available form.

The methods used in sowing their crops, likewise, display much skill in dealing with the existing conditions. Since experience has shown that seed placed in a dry soil is usually wasted, planting is not done until sufficient moisture is present in the soil to bring about germination. But on years when the spring rains are delayed or absent, farmers plant not what they most desire, but what they can.

Fortunately, there is available for their choice a large selection of crops and varieties having different lengths of growing period. These include kaoliang, black and yellow soybeans, millet of many varieties, small green soybeans and buckwheat. The proper season for planting each of these crops is thoroughly understood by all farmers, and seed is somehow always secured to meet the various rainfall situations usually encountered. The result is, that unless rains fail completely, no land remains

THE MULE AS AN AID TO THE FARMERS OF SHANSI

TOP: *left:* This newly-introduced water wheel, which draws water more quickly than hand labor, is gaining many users. The donkey is blindfolded so that he will follow without question the pull on his bridle exerted by the lead rope. *Right:* A donkey is helping to prepare the winter's supply of millet. The stone roller, which the blindfolded animal is pulling, cracks from the kernel the thin husk in which it grows. The small fanning mill, standing nearby, will later blow out the inedible chaff. MIDDLE: *left:* The old-fashioned plow is not always easy to operate. This implement is handled easily under ordinary conditions, but when ground is hard the plowman often finds his job difficult. *Right:* The sure-footed donkey is a dependable mountain animal. Steep and narrow trails are easily negotiated by this beast, which is commonly used to transport grain from mountain villages to distant market centers on the plain. BOTTOM: *left:* At planting time a locally devised stone packer is indispensable. This ingenious device is a very important factor in the success of Shansi farmers owing to the semi-arid conditions, for it prevents the evaporation of moisture. *Right:* Two make a team, regardless of breed. This ox and mule are pulling the common type of harrow. Because farms are usually small, a good team of animals is the exception.



SOLVING IRRIGATION PROBLEMS IN A LAND OF LITTLE RAIN

TOP: *left:* This small stream, a natural source of water, has made this typical loess canyon with its vertical cliffs and curiously shaped pinnacles. Though a stream may flow only during the rainy season, it can quickly cut through deep soil deposits. Because most of the soil materials are calcareous, a protective coating forms on exposed surfaces, and this is in large part responsible for the vertical cliffs and other peculiar shapes that play so important a part in giving loess regions their distinctive appearance. *Right:* Wells provide the source of a good deal of irrigation water on the plains. Frequently the water is drawn by hand from a depth of thirty feet in closely woven willow baskets. This method is very laborious, but irrigated wheat will produce twice as much as unirrigated, which is all the argument these farmers require. MIDDLE: *left:* A bridge serves as a conduit for irrigation water. A small channel provided at the side of this bridge conducts water over a formidable gulley. On the other side it will irrigate small patches of wheat on the fertile soil of a valley bottom. *Right:* When planting time finds the soil depleted of moisture, when possible water is usually run into the rows in which the seeds are planted, or about to be planted. BOTTOM: *left:* Preparing the basins used in a common method of applying irrigation water. The flow of water from wells is usually not large enough to flood a large area at one time; so small basins of this sort are made. These are filled one after the other until the entire field has been covered. *Right:* These farmers are carrying water from the streams below to irrigate newly planted apple trees on the upper terraces. It is a strenuous chore, but all a part of the day's work to mountain fruit growers.

entirely idle. A harvest of some kind, representing the best available under the conditions of that year, is obtained.

Since spring rains are always light, there is frequently present a problem of germination. The seedlings of certain important crops, like kaoliang and millet, have a remarkable ability to hang on during periods of drought, neither growing much nor dying, but then to shoot rapidly upwards when rains finally come. The problem is to get the young plants above the ground.

This difficulty must have taught these farmers, long ago, to pack soil firmly around the newly planted seed. To accomplish this object they have devised an ingenious packer, which must be rated as one of the important factors in their success in farming this dry region. Without it, failures would often result where successes are now obtained.

The essential part of this implement is a set of two or three small, circular stone rollers, which are rounded on the edges to give an appearance like balloon tires. These rotate on axles whose ends are fastened to a simple wooden frame. For nearly all planting on dry land, this packer is pulled by men or an animal through the furrows of the freshly drilled rows. By this method there are eliminated spaces through which desiccating air would circulate, and moist soil is packed close to the seed to start its germination.

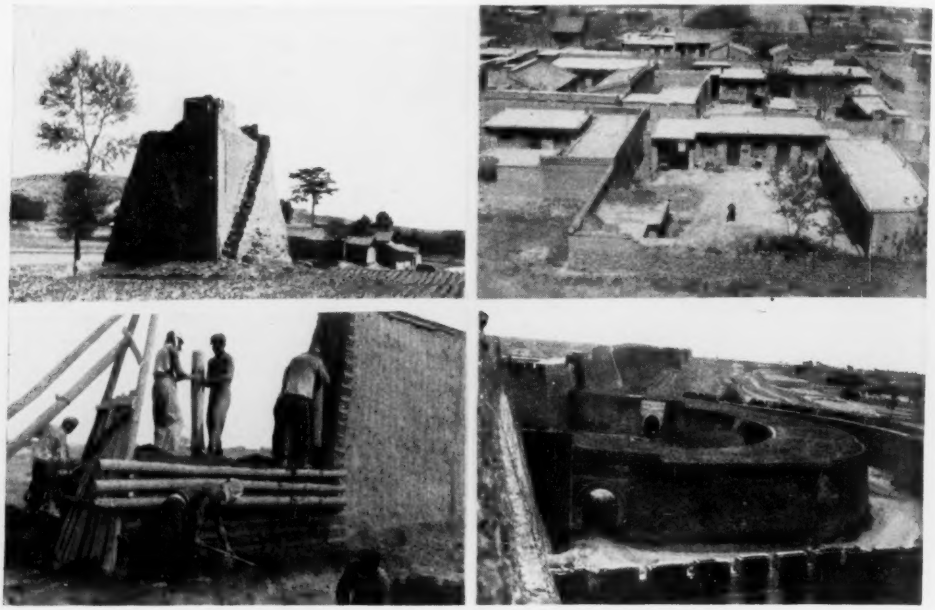
Where possible land is irrigated with water either from streams or from wells. In irrigating wheat during the spring months, it may often be observed that farmers spend long hours laboriously drawing water from wells, not only when the weather is dry but frequently just after a rain has fallen, sometimes even before it has fully stopped raining. The casual observer may consider that, because there has just been a rain, it is unnecessary to irrigate at such times. But the native tells you that an application of water, then, will help insure that the kernels be well filled out later.

In this he is right. Rains at this season of the year seldom penetrate to a greater depth than six or seven inches. From this thin layer of moistened soil the water is soon evaporated by a drying sun and wind.

An irrigation immediately after the rain has fallen forces this moisture downward, to create a reserve which can be drawn upon during the hot dry days that follow.

The same sort of an understanding of how best to manage under existing conditions is seen in certain practices common in sheep raising. The fat-tailed breeds raised in this region are of types which can be bred during the summer months; and farmers see to it that ewes are bred as early in the season as possible. It happens, therefore, that lambing begins in December, about two months earlier than in the United States. For Shansi conditions this is a fortunate circumstance. Because of the scant winter pasturage, sheep are often reduced, by spring, to an emaciated condition. In this state they are not able either to properly nourish unborn young or to provide sufficient milk for the use of offspring following birth. In December and January the ewes are still in comparatively good condition, and lambs, born at this time, are sturdier when born and make a more rapid growth subsequently than when born later.

The difficulty attending this practice is that lambs are born in the severest part of the winter, and special care is required lest the new-born young die of exposure. When flocks are pastured near the owners' homesteads, ewes about to lamb are retained in the courtyard where proper care is given them. But when sheep are on the range, as in Inner



ANCIENT STRUCTURES AND MODERN BUILDING TECHNIQUE
TOP: *left:* Remains of old signal towers are still found along roads which were main routes of the old empire, the relics of a time when express messages were sent by signal fires. *Right:* Nearly all Shansi farmers live in homes built on the courtyard plan. The entrance gate appears at the rear, while at the front on the left is the shed for farm animals. BOTTOM: *left:* Mud is cheaper than brick for a wall to enclose the courtyard. Numerous walls, sometimes even city walls, built by pounding moist earth in molds, may maintain their form and serve for decades, due to the dry climate. *Right:* Double defense gates guard the entrance to the old city of Pingyangfu. The site occupied by this important city in southwest Shansi has been inhabited continuously for several thousand years. Its well-built walls would not be impregnable under conditions of modern warfare, but they were useful even as late as 1936 when Chinese communist troops unsuccessfully sought to force an entrance.

Mongolia, a stable is not always conveniently at hand, and other means of caring for the lambs must be provided.

It was the writer's fortune to be present on one occasion when a lamb was born under such circumstances. Curious to see how the situation would be handled, I watched the procedure. Before the lamb had gotten fully to its feet a shepherd appeared, with a heavy felt bag containing several compartments. Into one of these the lamb was nonchalantly at once slipped, and kept there until eventually it was taken back to shelter. We were informed that, in the large flocks pastured in those regions, as many as twenty to thirty lambs may be born and handled after this fashion in one day.

In practices such as these there is portrayed a great deal of the genius of Chinese agriculture: a prodigious use of human labor, careful attention to the details of farm operation, the employment of methods well-planned to overcome difficulties created by the natural environment, a full utilization of all available resources and a use of these resources in ways which will support the maximum number of human beings.

Yet, in spite of the undoubted excellence of certain practices, there remains a good deal which is short of perfection as judged from the standpoint of mod-

SHEEP AND THEIR RELATION TO AGRICULTURE IN NORTH CHINA

TOP: *left:* The fat-tailed native sheep convert waste crop remains into salable wool and mutton. Livestock in China is expected to live, for the most part, on waste products which the human population can not directly utilize. *Right:* Sheep on mountain pasture provide a boon to mountain crop farmers, who pay cash to have them stabled there because of the fertilizer which they will leave. To the left plows and oxen may be seen standing ready to turn under the additions as soon as the land is vacated, lest a drying sun disperse any of the value into the air. BOTTOM: *left:* A newborn lamb is about to be saved from freezing. Lambs are sometimes born on the open range, away from shelter. To prevent their freezing, shepherds provide heavy felt bags into which lambs are slipped at birth and carried back to the village. *Right:* Rambouillet rams have been imported from Montana to improve native sheep. Preliminary experiments show that crossbred sheep, obtained by crossing this ram with native ewes, produce wool which is worth four times as much per animal as that from present breeds.

ern scientific information. Farmers, generally, do not understand the important practice of seed selection. Fields are not always kept scrupulously free of weeds. And deeper plowing would increase yields from between ten and fifteen per cent., as experimental tests have demonstrated.

At threshing time, bundles of wheat or the severed heads of millet and kaoliang are spread out on a floor of pounded earth. The grain is then beat out with a stone roller, which is pulled round and round while an attendant brings to the surface, with a heavy wooden fork, the unthreshed portion below. This method has the advantage of requiring little outlay for machinery, but it leaves the grain dirty and mixed with grit. Occasionally, caught by an unexpected rain, the grain is seriously damaged. A small threshing machine, owned cooperatively, might be economically feasible and would overcome these difficulties.

Methods of dealing with disease and insect pests are crude and often ineffective. To control a serious pest on the apple and pear, the leaf roller, farmers scrape the bark during the winter and remove infested leaves after the worms have appeared. Their insistence that scraping has value is supported by scientific evidence that eggs of this insect are laid on the bark. But the method as

used is only partially effective and very laborious. Against many other pests—smuts of grain, aphis on cotton and kaoliang, various fruit insects and diseases and parasites of animals—they have little or no defense.

Neither has general use been made, as yet, of improvements that might become available through the use of scientific techniques applied to existing problems. Possible improvements of this sort include better strains of crops and breeds of livestock, new fertilizing materials, more satisfactory methods of disease and insect control and more efficient implements of the simpler kinds. That improvements of this sort may be looked forward to is being demonstrated in the work of experiment stations already established. It is to be expected that, when stable conditions return, rapid progress will be made in incorporating such improvements into general practice.

While war continues, not only is it impossible to make much advance along such lines in the penetrated areas, as in Shansi province, but the rural people who remain there suffer intensely. The course of the war has already seen innumerable villages burned, farm animals appropriated or destroyed, personal possessions lost and the ordinary flow of goods to market disrupted. A severe drought has added to the misery.

Of the future, one thing is certain. The life and farming practices of the rural inhabitants of this region will from now on rapidly change. Social movements, economic developments, political changes and scientific contributions to agriculture will all have a part in altering the life and farming practices which have been. Not for very much longer will this agriculture remain in the unique traditional form into which it has been fashioned by many centuries of a nearly indigenous development.

But few fears need be entertained that the farmers of this region will be incapable of making the necessary adjustments to the new conditions. These sturdy people are unafraid of hard work, eager to live, accustomed to hardship, painstaking in their efforts and ready to adopt new methods when of proven value. When to the heritage received from the experiences of past generations there is made available to them the improvements which investigations scientifically conducted will contribute, there should emerge, on a new level, an agriculture as worthy of respect in the new world as was the old system in the old.

BRITTLE TEMPERATURE OF RUBBER

By M. L. SELKER

CHEMICAL LABORATORIES OF THE BELL TELEPHONE LABORATORIES

INTEREST in the behavior of natural and synthetic rubber at low temperatures has grown considerably in recent years. Airplanes flying at very high altitudes and motor vehicles operating in arctic climates may encounter extremely low temperatures, and since both use rubber compounds, the need for precise knowledge of the behavior of rubber at low temperatures is essential. It has been known that rubber compounds become brittle at very low temperatures, but no published accounts have been found that give the effects of various factors on the brittle temperature for a wide variety of materials. Rubber is used primarily because of its insulating and elastic characteristics, and since the value of rubber insulation is largely lost if the material cracks under shocks at low temperature, the appearance of brittleness seriously affects the insulating power of the rubber as well as its elastic characteristics. The brittle temperature thus determines to a large extent the usefulness of rubber and similar substances at low temperatures.

When crude rubber is held at a moderately low temperature for some days, say in the neighborhood of 14° F, crystallization will occur. The rubber will get stiff and opaque, but will remain elastic to some extent; it can be stretched slightly and be bent without breaking. Well-vulcanized rubber does not crystallize, but as the temperature is lowered, it loses its ability to retract when stretched. If either crude or vulcanized rubber is cooled to some 70 or 80 degrees F below zero, however, it loses its elastic properties completely. If bent suddenly at right angles, it will break off very much like glass. It has been found that this transition to brittleness occurs at a sharply defined temperature, which is different for various natural and synthetic rubbers.

To assist in the study of the brittle temperatures recently made in these laboratories, the simple apparatus shown in Fig. 1 was constructed. A quadrant arranged to carry as many as six rubber specimens is mounted on a shaft, which may be turned with a simple crank, and is supported in a narrow insulated tank into which acetone and dry ice, or other cooling solution, may be placed. The specimen to be tested is fastened to the quadrant and turned down into the cooling solution long enough for it to assume the temperature of the bath, which is determined by suitable thermometers. A quick rotation of the crank then brings the specimen sharply up against a rigid metal bar projecting from the edge of

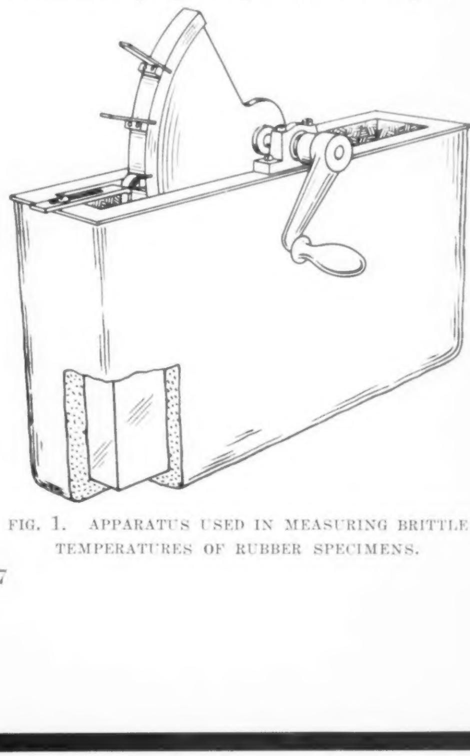


FIG. 1. APPARATUS USED IN MEASURING BRITTLE TEMPERATURES OF RUBBER SPECIMENS.

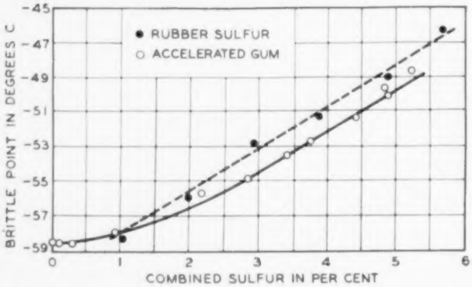


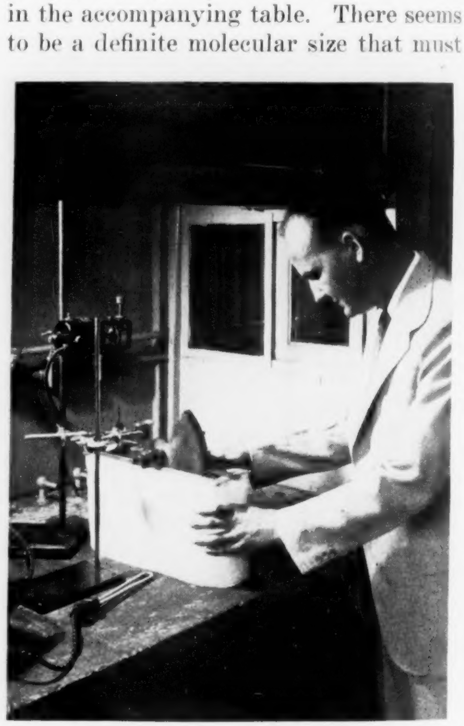
FIG. 2. RELATIONSHIP BETWEEN BRITTLE TEMPERATURE AND PERCENTAGE OF COMBINED SULFUR.

the tank toward the rim of the quadrant. If the brittle temperature has not been reached, the specimen will bend, but if it has, the specimen will break off cleanly. It has been found that the rubber becomes so tough at these low temperatures that considerable force is required to break it, and because of this only a single specimen is usually mounted on the quadrant.

With this apparatus a series of tests were run on a wide variety of natural and synthetic rubbers. It was found that the brittle point of soft vulcanized rubber, which is about −75° F, is essentially the same for all the vulcanizing periods common in industry. Certain of the synthetic mixtures show the same behavior. With rubber compounds vulcanized with an accelerator and a large amount of sulfur, or with sulfur alone, it was found that the brittle temperature varied nearly linearly as the amount of chemically combined sulfur. This is shown in Fig. 2, which gives data for a rubber-sulfur stock and an accelerated stock.

All the usual rubber compounds, the studies indicated, have brittle temperatures above that of crude rubber. Any addition of asphalt or resin, and of many oils, tends to raise the brittle temperature a few degrees. Zinc oxide and carbon black, however, can be added in large quantities with but small effect. The use of appreciable amounts of coarse fillers such as calcium carbonate, on the other hand, produce compounds with high brittle points after vulcanization. The various types of reclaimed rubber can be distinguished on the basis of their brittle temperatures, that from tire-tubes having the lowest. Only two of the synthetic rubbers are comparable to natural rubber in elasticity at low temperatures. Synthetic rubbers also differ from natural rubber in having higher brittle temperatures than their compounds.

There seems to be a relationship between brittle temperature and the size of the molecule of the substance. In general the large molecules have lower brittle temperatures than the small, but the change seems to be sudden rather than gradual, as is indicated by the data in the accompanying table. There seems to be a definite molecular size that must



APPARATUS AND OPERATOR

TABLE I

VARIATION OF BRITTLE TEMPERATURE WITH MOLECULAR WEIGHT

Material	Approx. molecular weight	Appearance	Temperature	
			°C	°F
Rubber	6,000	viscous brown liquid—solid	−48	−54
"	30,000	masticated pale crepe—soft, tacky	−61.5	−79
"	100,000	pale crepe—elastic solid	−61.5	−79
Polyisobutylene	1,500	viscous liquid	−23	−10
"	10,000	very viscous liquid	−50.2	−58
"	100,000	elastic solid	−50.2	−58
Polyethylene	low	soft, waxy	−15	+5
"	high	tough, waxy but hard	−68.5	−91

be attained before the brittle temperature characteristic of the material is reached. For rubber, this size corresponds to a molecular weight between 6,000 and 30,000, while for polyisobutylene it is between 1,500 and 10,000. The difference between the brittle temperatures for large and small molecules may be very great, as exemplified by polyethylene, which has a brittle temperature of +5° F for small molecules, and −91° F for the large.

COAL HYDROGENATION

It has been interesting to learn that substantial appropriations have been made for further experiments in coal hydrogenation in the U. S. Bureau of Mines and to read the appeals of experienced engineers. They urge that we begin now to acquire technical information on how best to handle American coals for the production of motor fuels, if for no other reason than to conserve petroleum for high octane fuels and the superior lubricating oils demanded by the modern Diesel and other types of engines.

Nothing quite equals the completion of such work well in advance of the time when it may be needed. The likelihood of early exhaustion of petroleum resources is no greater than it seemed to be a decade ago, but so far as we know petroleum is not being replaced by nature and it is being used at an enormously increased rate by all the nations that can lay their hands upon it. It is none too early to undertake very seriously the type of research and development that would lead to the proper use of coals for the manufacture of synthetic liquid fuels and particularly to provide the lubricating oils not duplicated elsewhere, not to mention the types of fuels which modern motive power utilizes to the best advantage. This does not necessarily mean beginning preparations for the third world war. It simply means taking precautions while we can to get the most out of our raw materials and to guard against the repetition of any of those wasteful procedures that have been so costly in the past. Let us learn all we can while we may. We should learn from present experiences the importance of time, particularly when there are differences in technique, opinion and policy.—*From an editorial, "Industrial and Engineering Chemistry," August, 1942.*

BACTERIA OF THE MARINE WORLD[1]

By Dr. CLAUDE E. ZOBELL

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ALTHOUGH the ocean has been described by bacteriologists as the "world's largest and most efficient septic tank," there are some land-locked biologists who question the existence of bacteria and allied microorganisms in the sea beyond the littoral zones influenced by terrigenous contamination. Certain text-books published during the last decade state that it is virtually impossible for bacteria to thrive in the open ocean, due to a multiplicity of adverse environmental conditions. Purportedly these include the high salinity of sea water, the paucity of organic matter, the processes of sedimentation, the abundance of natural enemies, the germicidal effect of ultraviolet radiations near the surface and the high hydrostatic pressure and low temperature at greater depths.

Believing that high hydrostatic pressures are inimical to life, the author of a recent text-book on general physiology concludes that bacterial putrefaction does not occur at great depths, a deduction which is contradicted by the recovery of viable bacteria from great depths and by evidence of bacterial activity on the sea floor.

Most of the early surveys indicated that while bacteria could be demonstrated in sea water from certain localized regions near land, for the most part bacteria should be regarded as ephemeral transients from a more favorable terrestrial environment. More recent surveys[1a, 2] which have been made in this country and abroad show that bacteria are quite widely distributed in the sea and that they probably play an important role influencing chemical, geological and biological conditions.[3] Specialized analytical methods have revealed the presence of active bacteria wherever water or mud samples have been collected; in mid-ocean more than a thousand miles from land, in water at depths exceeding three miles and buried in fifteen feet or more of bottom sediments.

BACTERIA IN SEA WATER

Bacterial populations ranging from a few hundred to several thousand per cc of water are not uncommon, although there are extensive oceanic zones where there are fewer than one bacterium per cc. The distribution of bacteria is influenced by several interrelated factors of which the concentration of utilizable organic matter is the most important. Usually there are more bacteria along the littoral zones than farther at sea.

Neither latitude nor water temperature directly influence the distribution of bacteria in the sea because extensive populations have been found in Arctic and Antarctic as well as in tropical regions. Wherever other organisms have been found (either plant or animal), careful studies reveal the presence of bacteria and allied microorganisms. Indeed, bacteria have been demonstrated in many marine environments where there is no evidence of other organisms existing.

Water samples from different depths of the sea have been obtained for investigating the vertical distribution of bac-

[1] Contributions from the Scripps Institution of Oceanography, New series, No. 169.

[1a] S. A. Waksman, SCIENTIFIC MONTHLY, 38: 35–49, 1934.

[2] W. Benecke, Abderhalden's Handb. der biol. Arbeitsmethoden, Abt. 404, Lfg. 404: 717–872, 1933.

[3] S. A. Waksman, *Ecol. Monogr.*, 4: 523–529, 1934.

teria by means of a pressure-resistant collapsible rubber bottle stoppered with a hermetically sealed capillary glass tube. The apparatus can be sterilized by boiling or autoclaving and lowered into the sea clamped to a hydrographic wire or cable. When the desired depth is reached a messenger (a weight which slides down the cable) is dropped. The messenger strikes a lever which breaks the glass tube two or three inches from any source of extraneous contamination, thus permitting the sterilized bottle to fill with sea water.

Living bacteria have been recovered from a depth of 5,000 meters where the hydrostatic pressure is around 500 atmospheres, or 7,500 pounds per square inch. Although it is not known how many bacteria may be killed by being hauled rapidly to the surface from great depths, experiments indicate that most bacteria tolerate such changes in hydrostatic pressure.

Bacteria, like nearly all other forms of marine life, are more abundant in the topmost 100 meters of water than in any zone at greater depths. This is attributed to the greater abundance of food in the upper zone which is derived directly or indirectly from photosynthetic organisms. The vertical distribution of the latter is limited primarily by the depth to which sunlight penetrates. Water temperature and the concentration of plant nutrients are also important factors.

The concentration of plant nutrients is influenced by the vertical movement of water masses[4] as well as by the mineralizing activities of bacteria. Water from the photosynthetic zone at stations

[4] H. U. Sverdrup, *et al.*, "The Oceans: Their Physics, Chemistry and General Biology," 990 pp. New York: Prentice-Hall, Inc. 1942.

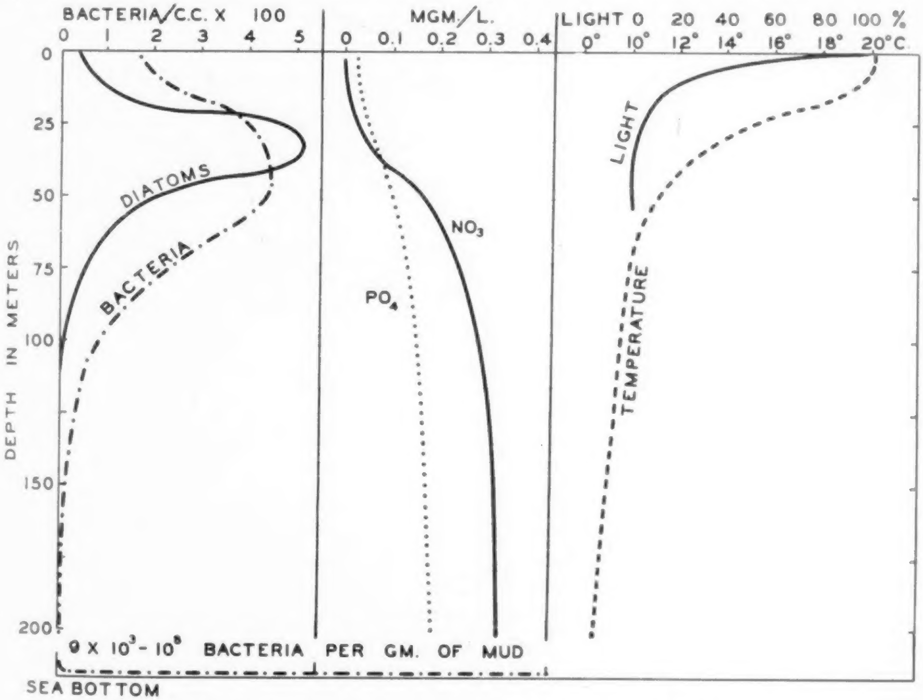


FIG. 1. VERTICAL DISTRIBUTION OF BACTERIA

(NUMBER PER CC OF WATER), DIATOMS (NUMBER PER LITER OF WATER), PHOSPHATE, NITRATE, LIGHT AND TEMPERATURE IN THE SEA BASED UPON THE AVERAGE RESULTS AT SEVERAL DIFFERENT STATIONS OFF THE COAST OF SOUTHERN CALIFORNIA

remote from land generally contains from a few to a few hundred bacteria per cc. Occasionally several thousand bacteria per cc of water are found in certain localized areas.

At all latitudes where observations have been made the number of bacteria decreases rapidly with depth. This is illustrated by Fig. 1, which also shows the vertical distribution of phytoplankton, nitrate, phosphate, temperature and light. One rarely finds more than one to ten bacteria per cc below 200 meters except on the sea bottom.

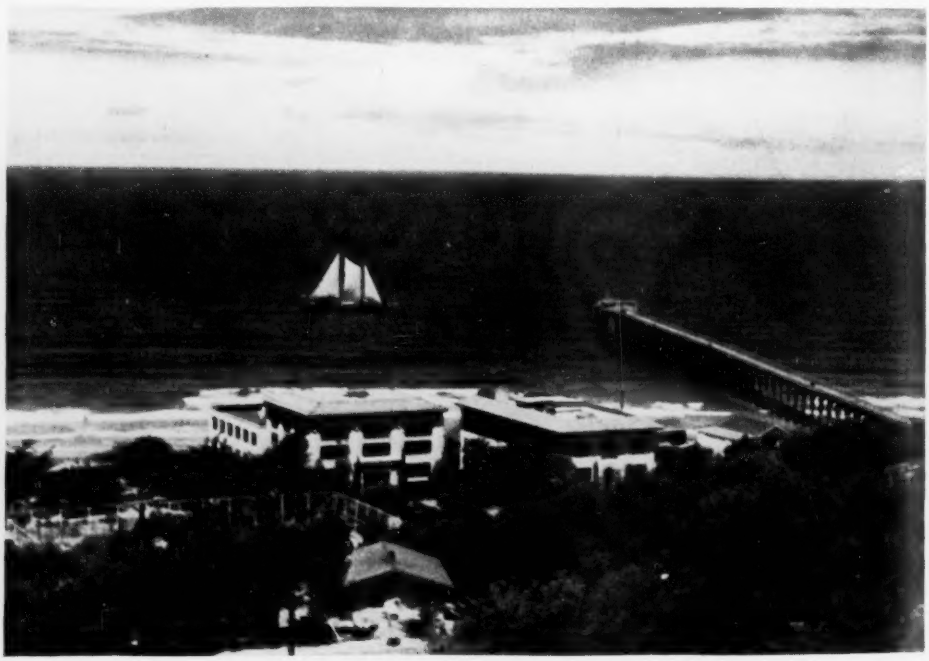
The analysis of water samples collected daily from the end of the S.I.O. pier for a period of ten years reveals that the seasonal distribution of bacteria tends to follow that of phytoplankton. As a rule the largest bacterial populations occur from January to March and the smallest from May to July. However, localized conditions often cause marked fluctuations from day to day.

Bacteria in Marine Mud

The richest microflora is found on the bottom of the sea.[5] In spite of the fact that the temperature may be from $-0.5°$ to $+2.5°$ C. and the hydrostatic pressure may amount to several hundred atmospheres, or a few tons per square inch, there are often as many bacteria in marine bottom deposits as in fertile garden soil. The topmost layer of mud which is in contact with the overlying water usually contains several million viable bacteria per gram. The number is not a function of the latitude or of the depth of the overlying water, but it is related to the particle size of the sediment and the organic matter content. These properties of the bottom sediment are influenced by oceanic circulation, bottom topography, distance from land and several other other interrelated factors.[4]

The vertical distribution of bacteria

[5] C. E. ZoBell, *Jour. Sed. Petrol.*, 8: 10–18, 1938.



THE SCRIPPS INSTITUTION OF OCEANOGRAPHY

THE *E. W. Scripps*, WITH THREE SAILS UNFURLED, IS SHOWN APPROACHING THE END OF THE PIER WHICH EXTENDS 1,000 FEET OUT INTO THE SEA.

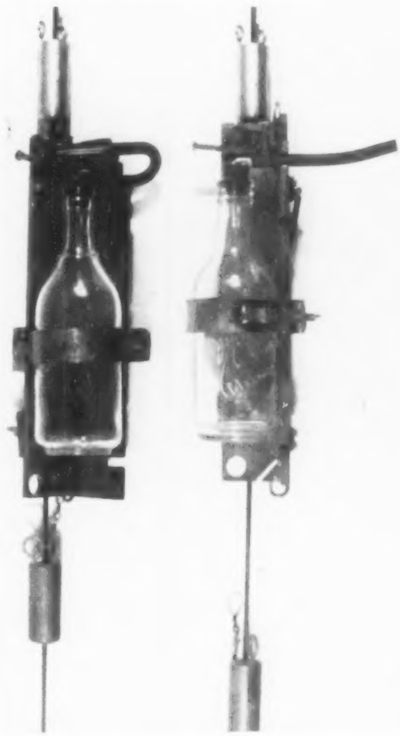
in the bottom deposits has been studied by analyzing long cylindrical cores of mud. The mud cores are collected in a celluloid-lined pipe. The pipe loaded with several hundred pounds of stream-lined lead weights is forced into the bottom mud when it is dropped rapidly, held in a vertical position by the dredging cable. The corer is hauled upon the deck of the research vessel by a power winch and the celluloid barrel full of mud is removed. Radially central portions of the mud cores representing strata from different depths are dissected out aseptically and bacteriologically analyzed.

In the bottom mud the bacterial population decreases from the surface with depth. The bacteria are unevenly distributed, probably due to their tendency to colonize and due to chemical and physical differences within the mud itself. On the average the number of bacteria decreases more or less exponentially from several million per gram at the mud-water interface to a few thousand per gram at depths exceeding 25 cm. Below this depth the decrease is slow and gradual, hundreds of bacteria per gram having been found in mud cores exceeding 500 cm in length. Table 1 shows the number of bacteria which were found in a long mud core collected from the lower end of the Gulf of California at a station where the water was 2,230 meters deep.

TABLE 1

VERTICAL DISTRIBUTION OF AEROBIC AND ANAEROBIC BACTERIA IN A MUD CORE COLLECTED FROM THE GULF OF CALIFORNIA WHERE THE WATER WAS 2,230 METERS DEEP.

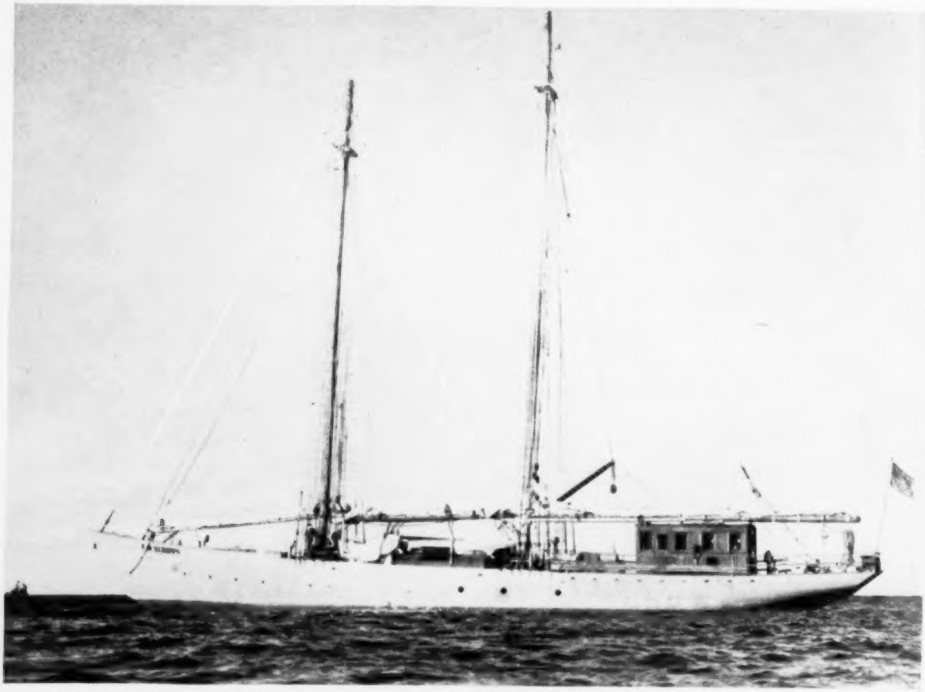
Core depth in cm.	Aerobes per gram	Anaerobes per gram
0– 10	62,000,000	8,900,000
10– 20	470,000	106,000
20– 30	235,000	73,000
40– 50	91,000	23,800
90–100	4,800	2,610
140–150	7,700	1,520
190–200	12,900	870
240–250	2,060	920
340–350	760	218
400–410	164	193
440–450	310	44
500–510	580	26



J-Z WATER SAMPLER

FOR BACTERIOLOGICAL WORK. THE WATER BOTTLE ON THE LEFT IS IN A POSITION TO COLLECT A SAMPLE OF SEA WATER. THE UPPER MESSENGER IS ABOUT TO STRIKE THE LEVER WHICH BREAKS THE CAPILLARY GLASS TUBE AT THE POINT INDICATED. WHEN THE TUBE BREAKS, THE PRESSURE RUBBER TUBING STRAIGHTENS OUT TO THE POSITION INDICATED AT THE RIGHT. SIMULTANEOUSLY THE LOWER MESSENGER IS RELEASED TO FALL ALONG THE HYDROGRAPHIC WIRE TO A SECOND WATER BOTTLE BELOW. GLASS BOTTLES AS ILLUSTRATED WITHSTAND HYDROSTATIC PRESSURE TO DEPTHS OF TWO OR THREE HUNDRED METERS; COLLAPSIBLE RUBBER BOTTLES ARE USED AT GREATER DEPTHS.

Aerobes as well as anaerobes occur in the mud. Although most of the bacteria have the faculty of living either in the presence or in the absence of free oxygen, some which appear to be strict aerobes are regularly found at the bottom of long mud cores where there is no free oxygen as manifested by the low oxidation-reduction potential and by the presence of hydrogen sulfide.



THE *E. W. SCRIPPS*

AN AUXILIARY SCHOONER, WITH RIGGING FOR UNFURLING 4,000 SQUARE FEET OF CANVAS, WHICH IS USED FOR STUDYING THE OCEAN.

The significance of the occurrence of strict aerobes in a highly reducing environment is a problem for speculation. Are they passive inhabitants of the anaerobic mud, preserved in a state of suspended animation since they were deposited from the oxygenated water several thousand years earlier, or do they respire and reproduce by a mechanism unknown to the microbiologist? Some of the secrets of life might be learned from the study of these unique marine microorganisms buried at the bottom of the sea.

Bacteria occur in the bottom deposits at depths far below that at which any other type of living organism is found. By consuming the oxygen from the interstitial water and otherwise rendering the environment reducing in character, they create conditions which are incompatible to the existence of other forms of life. The bacteria slowly decompose the organic matter which rains down from above, thereby effecting the chemical composition of the mud as well as altering its physico-chemical properties including the hydrogen-ion concentration and the oxidation-reduction potential.

Characteristics of Marine Bacteria

The bacteria which are isolated from the sea at places remote from possibilities of terrigenous contamination differ from their terrestrial cousins in many respects. Morphologically they are essentially like those which are indigenous to fresh-water or terrestrial environments with only minor points of difference.

Bacilli, or rod-shaped bacteria, constitute around 63 per cent. of the marine microflora, 5 per cent. are cocci or spherical and 32 per cent. are spirilla or helicoidal in shape. They average somewhat less than one micron in diameter. A large proportion of them are actively

motile by means of one or more flagella. Gram-negative forms predominate. Only a small percentage of them form endospores. Under suitable conditions somewhat more than half of the bacteria from the sea are chromogenic, producing yellow, orange, brown, red, purple, blue or sometimes green pigments.

Physiologically, marine bacteria are more distinctive, differing from terrestrial bacteria particularly in their salinity requirements. Most of the bacteria from the sea require sea water for their growth following initial isolation, while the bacteria from soil, sewage and other terrestrial sources grow poorly or not at all in sea water media. As shown by Table 2, only 8 to 17 per cent. of the

TABLE 2

RELATIVE NUMBERS OF BACTERIA IN MARINE AND TERRESTRIAL MATERIALS WHICH GREW IN NUTRIENT MEDIA PREPARED WITH SEA WATER AND OTHER SALT SOLUTIONS.

Sample	Number of samples analyzed	Salt solution used to prepare nutrient media: Natural sea water	Tap water	Synthetic sea water	3.0% NaCl
Sea water ..	12	100	8	78	56
Marine mud	12	100	17	73	64
Sewage	8	13	100	34	29
Tap water .	8	3	100	40	31
Soil	8	14	100	52	46

bacteria from sea water or marine mud grow in fresh-water media, while only 3 to 14 per cent. of those in sewage or soil grow in sea-water media. Neither synthetic sea water nor isotonic salt solution is an entirely satisfactory substitute for natural sea water.

Curiously enough, natural sea water is more toxic for fresh-water bacteria than is isotonic synthetic sea water. This is partly due to the presence in sea water of minute concentrations of thermolabile substances probably organic in nature which are bactericidal or bacteriostatic for fresh-water bacteria but do not injure marine forms.

Contrary to popular conception very few marine bacteria are halophilic or salt tolerant. Most of them require around 3 per cent. salt, but very few marine bacteria tolerate salt concentrations exceeding 6 per cent. Paradoxically a larger percentage of terrestrial than marine bacteria can grow in solutions containing from 6 to 10 per cent. salt. Korinek[6] and others[7] report that in general terrestrial or fresh-water bacteria tolerate changes in salinity and osmotic pressure better than marine bacteria.

The specific salt requirement of marine bacteria may account for the failure of early investigators to find appreciable numbers of bacteria in the sea except in bays, estuaries and littoral water laden with land contaminants. Being guided by conventional standard methods for the bacteriological analysis of water, the investigators prepared their media with fresh water or with ordinary salt.

Many present-day workers are investigating the bacterial flora responsible for the spoilage of catches of marine fish using fresh-water media. Upon a basis of such observations, they conclude that fresh-water or terrestrial bacteria are primarily responsible for the decomposition of marine fish. Other investigations indicate that there are many more proteolytic bacteria associated with marine fish which will grow on sea-water media than those which will grow on standard fresh-water media. This observation leads us to believe that if marine bacteria are treated as physiologically distinctive species, very different conclusions concerning the microflora of living and dead marine fish will be reached.

A large percentage of the bacteria found in the sea are actively proteolytic as indicated by their ability to liquefy gelatin or to decompose virtually all types of nitrogenous compounds with the liberation of ammonia. As a rule they

[6] J. Korinek, *Centralbl. f. Bakt.*, II Abt., 66: 500–505, 1926.

[7] C. E. ZoBell, *Jour. Mar. Res.*, 4: 42–75, 1941.

are less actively saccharolytic than fresh-water or terrestrial bacteria in general, although among the hundred or so species of marine bacteria which have been studied are representatives which attack all the simple carbohydrates. Bacteria which digest starch, cellulose, chitin and lignin occur in the sea. Agar liquefiers are noted on nearly every plate inoculated with sea water or marine mud. Photogenic or luminescent bacteria are also common in the sea. Sometimes enough of them develop in sea water stored in the dark to make it glow with cold light.

Temperature Requirements

Since over 80 per cent. of the ocean is perpetually colder than 5° C., it is not surprising to find that many bacteria from such an environment are able to grow at relatively low temperatures. Although food refrigeration is founded on the principle that low temperatures inhibit bacterial activity, many marine bacteria grow well at refrigeration temperatures. Several species have been studied which multiply and are otherwise physiologically active at temperatures ranging from 0° to −11° C. Indeed, most marine bacteria multiply at 0° C. These cold-loving organisms are sometimes very troublesome in the spoilage of refrigerated foods, uncured furs and other products from the sea.

Marine bacteria as a group are much more thermosensitive than are most terrestrial bacteria. The ability of a group of pure cultures of marine bacteria to survive or to multiply at different temperatures is illustrated by the data in Table 3. Very few marine bacteria survive at temperatures which are optimum for the growth of many terrestrial bacteria, 30° to 37° C. Some marine bacteria are actually killed in 10 minutes at 30° C. Only about half of the marine bacteria studied by the author survived at 37° C. for ten minutes. However, as on the land there are a few spore-formers

TABLE 3

Number of Pure Cultures of Marine Bacteria which Survived at Different Temperatures for Ten Minutes and the Number which Multiplied in Nutrient Media at These Temperatures, 128 Being the Total Number Tested.

Temperature	Survived	Multiplied	Temperature	Survived	Multiplied
− 4° C.	128	103[a]	42° C.	51	8
+ 3° C.	128	128	45° C.	40	2
22° C.	128	128	50° C.	23	0
25° C.	128	112	60° C.	9	0
30° C.	123[b]	89	80° C.	7	0
37° C.	61	18	100° C.	2	0

[a] Evidence of multiplication after three weeks.
[b] Survived stated temperature for ten minutes.

in most samples of marine materials which are not killed by the boiling temperature of water.

There are very few terrestrial bacteria which can not withstand 50° C. for ten minutes, but the average marine bacterium is so thermosensitive that it might be inactivated by unduly prolonged exposure to the plating temperature of nutrient agar, 42° C. This psychrophilic thermosensitive characteristic of marine bacteria must be taken into consideration in dealing with them or in evaluating their importance in the world below sea level or their relation to man.

Importance of Bacteria in the Sea

Marine bacteria are not merely biological curiosities. In spite of their minute size, they can be characterized as the mighty mites of the deep in view of their far-reaching effects upon conditions in the sea. Although they are so small that individuals must be magnified nearly a thousand diameters before they can be seen, the standing crop of bacteria in the oceans of the world is estimated to be no less than ten million tons. If they multiply only once a day (and the generation time of some is known to be less than an hour), the annual crop of marine bacteria would exceed 3 trillion tons. These are minimum estimates

based upon an average bacterial population of ten bacteria per cc, each weighing an average of 5×10^{-13} gm.

However, it is not by their mass but by "their works that ye shall know them." And, indeed, we are much more interested in their activity than in the organisms as individuals. Experiments which have been designed to simulate conditions in the sea indicate that bacteria influence the composition and concentration of nitrogen, sulfur and phosphorus compounds as well as the organic content of sea water. Bacteria are present which can oxidize or reduce nitrogen and sulfur compounds; they liberate phosphate from phosphorus compounds, and they mineralize waste organic matter to give carbon dioxide and other plant nutrients.

It is due to their efficiency in mineralizing organic matter that the sea has been characterized as "the world's largest and most efficient septic tank." The organic content of the ocean is kept well below ten parts per million in spite of the extensive animal population and terrigenous pollution.

Bacteria are probably more important than any other group of organisms in reducing the oxygen tension of sea water. There are enough respiring bacteria present to utilize from 0.1 to 5.0 cc of oxygen per liter of water per year in different parts of the ocean. In certain localized regions where oxygen is not readily replaced from the atmosphere or by photosynthetic activity, they utilize the last trace of dissolved oxygen often causing extensive "oxygen deserts."

As a source of food bacteria are consumed by many animals both large and small. Not only do protozoa, copepods and other microscopic animals thrive on a bacterial diet; macroscopic animals, including mussels, oysters, tunicates and worms, can live indefinitely on bacteria.[8] Many animals dwelling at or near the bottom where bacteria are abundant probably derive much of their nutrition from the bacteria which they ingest.

Bacteria as Geological Agents

Through their effects on the chemical and physico-chemical conditions in bottom deposits bacteria exert a far-reaching influence on the diagenesis of sedimentary materials. As the principal dynamic agencies which alter the hydrogen-ion concentration they tend to precipitate or dissolve calcium carbonate (limestone), depending upon whether they increase or decrease the hydrogen-ion concentration. Bacteria are present in marine bottom deposits which can do either, the direction and magnitude of the change being largely a matter of organic, sulfate and nitrate content.

Under favorable conditions bacteria play a role in the deposition of bog iron and in the precipitation of manganese compounds. While there are specific bacteria which oxidize iron and manganese, the state of these metals in sedimentary materials is primarily a function of the oxidation-reduction potential. The latter is influenced by bacterial action.

Certain bacteria transform sulfur compounds, often giving rise to sulfides, free sulfur or sulfates. The decrease in the quantity and changes in the nature of organic matter in sedimentary materials in the initial stages of lithification are attributable primarily to the activities of the microflora.

Do Bacteria Produce Petroleum?

It is still indeterminate if bacterial activities play a role in the genesis of petroleum. In fact, the origin of petroleum is still a mystery, although it is the consensus of oil geologists that petroleum is derived from the transformation of organic matter at the bottom of the sea by either biological, chemical or geophysical agents; probably all three.

[8] C. E. ZoBell, *Jour. Mar. Res.*, 1: 312–327, 1938.

Bacteria possess certain unique properties by which they could contribute to the formation of petroleum and they are present in potential source beds of petroleum in significant numbers.

By reducing the oxygen, nitrogen and phosphorus content of organic matter, bacteria convert it into substances which are more petroleum-like. This is illustrated by the data summarized in Table 4. Very low oxidation-reduction potentials created by bacteria in certain environments are theoretically conducive to the formation and accumulation of hydrocarbons. Methane-producing bacteria occur in marine bottom deposits and it has been postulated that methane might be polymerized geophysically with the formation of higher hydrocarbons. It is not improbable that certain complex hydrocarbons are produced directly by bacterial action on marine sapropel.

TABLE 4
PROXIMATE ANALYSIS OF ORGANIC MATTER FROM DIFFERENT PETROLIFEROUS ENVIRONMENTS

Source of organic matter	Carbon	Hydrogen	Oxygen	Nitrogen	Phosphorus
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Marine sapropel	49	5	40	3.4	0.8
Recent sediments	58	7	34	2.2	0.6
Ancient sediments	73	9	14	0.9	0.3
Petroleum	85	13	0.5	0.4	0.1

The occurrence of sulfate-reducing bacteria in oil-well brines and in petroliferous marine sediments, together with the accompanying lower sulfate-chloride ratio, suggests a relationship between these bacteria and the formation of petroleum. Bacteria which oxidize various waxes, oils and other hydrocarbons may be instrumental in the destruction of petroleum under certain conditions.

Disease-Producing Bacteria

Although marine bacteria are predominantly beneficial, there are a few which are pathogenic or disease-producing. Very few of the bacteria which inhabit the sea are pathogenic for marine animals, and as far as is known, none of them cause disease in man. Typhoid bacilli, the vibrio which causes Asiatic cholera and certain other human pathogens, may remain alive for a few days after being discharged into the sea, and hence sea water polluted by man is a potential source of danger, but fortunately such bacteria do not live long in the sea.

It is estimated that there are enough coliform bacteria discharged by the sewage effluents along the west coast of the United States each day to give over a hundred for every liter of water in the North Pacific Ocean if they were uniformly distributed. Yet one seldom finds coliform bacteria in the sea, except in bays or in the immediate proximity of sewage effluents, because they are destroyed so rapidly. However, in the latter places, untreated sewage may be very dangerous to bathers or consumers of shell-fish as well as esthetically offensive.

There is evidence that certain marine animals succumb to bacterial infections. However, the conditions of life in the sea are not conducive to the propagation of pathogens, although parasitic animals thrive there. As soon as a pathogen incapacitates his host, the latter almost immediately falls prey to the ever-present predator and the evidence is destroyed. There is no sanctuary in the sea for the ill or the old where only the fittest survive.

Any diseased fish or other animal which can no longer swim quite as fast as his companions is soon captured and probably eaten by a larger fish or other predator. Consequently the pathogen which incapacitates his host is destroyed also, unless the pathogen can attack the predator. Thus, to incapacitate his host, the pathogen is committing suicide.

Nevertheless, there are some marine pathogens which continue to take their toll of both plants and animals inhabiting coastal waters. A few years ago the lobster industry on the West Coast was threatened by a "soft shell" disease which killed large numbers of lobsters and made others unsuitable for human consumption.

In aquaria, experimental tanks and elsewhere in captivity, many marine animals have their resistance weakened to such an extent that they become victims of bacterial infections. Similarly, kelp, eel grass and other marine vegetation sometimes become infected with devastating pathogenic microorganisms when the resistance of the plants is lowered by storms, man's pollution or otherwise. Bacteria have been observed which injure the pneumatocysts or float bladders of kelp causing the kelp to sink to the sea floor, where it dies and rots. In general, though, while marine bacteria have a predilection for living associated with plants or animals as symbionts, commensals or epiphytes, they rarely injure oceanic hosts.

Sessile Habit of Bacteria

Contrary to popular conception, it is doubtful if many marine bacteria are planktonic or free-floating organisms. Most of them seem to occur attached to objects larger than themselves, such as plants or animals, settling particles of sediment, the remains of dead organisms or other particulate material. This peculiarity of marine bacteria has been attributed to the fact that organic matter is concentrated by adsorption upon solid surfaces where the bacteria can feed more efficiently when attached than when the bacteria are swimming or floating about in dilute nutrient sea water.

Some bacteria have a mechanism for attaching themselves to objects, some are stereotactic, others are adsorbed on solid surfaces and still others are able to grow only on bodies where nutrients are concentrated. Bacteria belonging to the latter category are especially abundant in sea water where organic nutrients are dilute.

Bacteria digest most of their food extracellularly or outside of their own bodies. They must render their food soluble by their digestive enzymes before the food can be ingested. Since there is less than 10 milligrams of organic matter per liter of sea water ordinarily, the bacteria have considerable difficulty in such a dilute medium trying to digest and ingest enough food to satisfy their nutrient requirements because it diffuses away from them about as fast as they can digest it. If, however, the bacteria are on a solid surface which will help to concentrate organic matter and to retard the diffusion of the soluble digested food away from them, they are able to thrive. Recent studies indicate that the solid surfaces also facilitate the orientation of the bacterial exoenzymes in the most advantageous position.

Fouling of Submerged Surfaces

This sessile sedentary habit of marine bacteria which causes them to localize on solid surfaces is sometimes inimical to man. Quite indiscriminately the bacteria grow on virtually all types of submerged surfaces, including ships' bottoms, hydroplane pontoons, water conduits and other man-made structures. After a few days' submergence in sea water the exposed surfaces are coated with a thin layer of bacteria along with other film-forming microorganisms.

The thin layer of film is rarely noticed unless one uses a high-powered microscope or other specialized analytical procedures, and by itself it is quite unobtrusive. However, the film attracts a myriad of tiny larval animals which permanently attach themselves to the surfaces. These attached animals, including barnacles, mussels, oysters, hydroids,

bryozoa and other "fouling" organisms, grow with surprising rapidity, and before many months they are clogging water conduits or seriously retarding the movement of vessels through the water.

There is evidence that bacteria influence the fouling of submerged surfaces in several ways: They discolor bright smooth surfaces which might otherwise discourage the attachment of fouling organisms. Bacteria serve as a source of food for the barnacle and his nefarious kin. They often protect the fouling organisms from the specific poisons in paints either mechanically, by adsorbing the poisons or by rendering the poisons inert by the production of hydrogen sulfide or other chemical substances. Under certain conditions they increase the alkalinity of the surface film, thereby favoring the deposition of the calcareous cement by which certain fouling organisms attach themselves. The bacteria produce plant nutrients which favor the growth of sedentary algae.

As much as 12 to 14 per cent. by weight of the fouling cumulation of ships' bottoms may consist of bacteria. We have isolated nearly fifty different kinds of sessile bacteria from such material, and other investigators are adding steadily to the list.

The so-called "fouling" organisms whose attachment is influenced by the primary film-forming microorganisms are most annoying and they necessitate the frequent drydocking of boats and the reconditioning or replacement of water conduits and other submerged marine structures at considerable cost. It is estimated that in times of peace, fouling organisms cost the United States Navy and merchant marine more than a hundred million dollars annually. In times of war the cost of fouling organisms is inestimable, considering how they retard the speed of vessels, increase fuel consumption and finally necessitate taking important vessels out of commission for cleaning in a drydock at a time when they may be urgently needed. The incrimination of bacteria and allied microorganisms as contributory agents dictates that they be taken into consideration in investigations designed to solve the problem.

Conclusions

Bacteria are widely distributed in ocean water and bottom deposits. Morphologically they resemble terrestrial bacteria, but they exhibit certain physiological characteristics and cultural requirements which are distinctive. Their sensitivity to temperatures exceeding 25° C., their ability to grow at low temperatures and their specific salt requirements are especially noteworthy.

Bacteria influence chemical, physicochemical, geological and biological conditions in the sea in many ways. Their possible relationship to the productivity of the sea, to the spoilage of marine products of commerce, to the genesis of petroleum and to the fouling of submerged surfaces are practical problems which command attention.

Further information on the bacterial population of the marine world will increase our understanding of oceanic phenomena and the marine environment besides contributing to our knowledge of bacteriology. Eventually it may become possible to apply such information to the control or amelioration of some of the harmful activities of bacteria and to take fuller advantage of those which are beneficial.

BIOLOGICAL CONTROL OF RODENTS AND PREDATORS

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INTRODUCTION

CONSIDERABLE success has been attained and much written on biological control of insect pests. The U. S. Bureau of Entomology has spent a large amount of the energy of its very able research staff on experiments with native and introduced insect parasites and predators attacking or likely to attack the major pests of crop and orchard. In the main these have of necessity been sought in other parts of the world or in other localities. Some of the pests which have been controlled by insect parasites or predators are: the citrus mealy bug, the terrapin scale and the cotton cushion scale. Many other pests are reduced in numbers by introduced enemies or natural enemies which have been fostered. The subject has developed to a point which enabled Dr. H. L. Sweetman, of the Massachusetts State College, to write a book of more than four hundred pages.[1]

The work on insect parasites has been one of the most expensive and at the same time most highly profitable research projects which the Bureau of Entomology has undertaken. Unfortunately, the method was of necessity one of cut and try. Men were often sent to remote parts of the world to study parasites and predators of insects related to a particular major pest. If parasites of promise were found they were brought to the United States. After being cultured in captivity, sometimes with serious difficulty, they were released where the pest which they were expected to attack was present and the results followed under field conditions. Many introductions have been successful, but many others have wholly or partially failed. Thus in all cases a large amount of work was necessary to bring the introduction to the final test. Roughly speaking, the failures may well have exceeded the successes, but the successes have been important enough to justify the effort and expense.

This work stands out in sharp contrast to the bungling treatment of the mammalian pest problems of the western grassland and other grazing lands of the United States and Canada. In 1901 C. Hart Merriam, chief of the U. S. Biological Survey, in an article in the yearbook of the Department of Agriculture,[2] outlined the *reverse* of biological control of rodents. This consisted of a description of the processes by which the enemies which had controlled the populations of prairie dogs and other rodents detrimental to agriculture had been reduced, resulting in the increase of the rodent populations to pest proportions. At that time it would have been easily possible to set up an experiment dealing with biological control of these pests. On the contrary, however, the use of poison was advocated. This was not new because cattle men of the plains had used poison for many years to control wolves, and the practice had no doubt been followed to some extent in the eastern states and probably in Europe. Dr. Merriam's article appears, however, to have been the beginning of federal

[1] Harvey L. Sweetman, "The Biological Control of Insects." New York. 1936.

[2] C. H. Merriam, "Prairie Dogs of the Great Plains." Yearbook, U. S. Dept. Agr., 1901: 257–270.

KIT FOXES, ORIGINAL ENEMIES OF GRASSLAND RODENTS

THEY LIE IN WAIT FOR THEIR PREY, AS DOES THE COYOTE. KIT FOXES WERE ABUNDANT AT ONE TIME, BUT ARE NOW VERY RARE. THEY ARE ESSENTIALLY HARMLESS TO MAN'S INTEREST.

advice to use poison, the sequel of which was federal support of poisoning undirected by research.

Previous to 1914 the various divisions and bureaus of the U. S. Department of Agriculture, especially the Biological Survey, made studies of the distribution and food relations of birds and mammals, and made efforts to standardize bounty systems for the control of predators in the several states, especially the western ones. In 1914 the Survey secured its first small appropriation for experiments and demonstrations in predatory animal control. These were probably merely experiments to determine what poison method was cheapest and least dangerous. The "experiments" were followed by larger appropriations for control of predatory animals. The intensity of this politico-economic campaign is illustrated by the fact that it was carried so far that the wolves and mountain lions were eliminated from Yellowstone Park, an area set aside in 1872 for the preservation and "retention in a natural condition" of the "(natural) curiosities within the park." These animals had also been given the right to live by an "act to protect birds and animals in Yellowstone National Park" passed in 1894.

It is important to understand at this point that studies which would have thrown light on the question of biological control of mammalian pests call for large areas of land on which the natural interactions of the important animals and plants can be studied. Although the Federal Government had set aside the Santa Rita Range Reserve in southern Arizona, in 1903, for the study of grazing problems, no biotic or bio-ecological

studies were undertaken for many years. However, in 1917 an agreement was entered into by the U. S. Forest Service, the Biological Survey, the Carnegie Institution of Washington and the University of Arizona to conduct cooperative bio-ecological studies with particular reference to rodents which were growing too numerous. This condition of the rodent population is the usual sequel of intensive campaigns of predator destruction such as had just preceded it. Bio-ecological studies were started soon afterwards with attention concentrated on the rodents. One of the early important papers from this source, "The Life History of the Kangaroo Rat," by Vorhies and Taylor,[3] appeared in 1922. It was followed by a goodly series of important researches during the succeeding 15 years. Meanwhile, various other studies have contributed much additional information concerning interactions of plants and animals.

The Grasslands

The outstanding mammal problems of the United States and Canada concern the grasslands of central North America. A discussion of the original condition and history of this area with special reference to animals will facilitate understanding of the possibility of biological control of plains animals. The grassland originally presented an excellent group of animals living in a state of dynamic balance. To the pioneer trappers the immense herds of bison meant free meat and free hides. Bison fitted the climate and grassland so well that *its population exceeded the present human population* on the same area. It is an outstanding indication of greed and prejudice, on the part of man, that it was destroyed so ruthlessly instead of being maintained as a meat producer. The antelope was also an important game animal. Associated with the spectacular ungulates were the wolf, coyote, badger and numerous well-known rodents such as the ground squirrels and the prairie dog. There was also a full quota of small predators such as the kit fox. To fully appreciate the relations of the animal to settlement and the development of pest problems it is necessary to review the history of the fauna during the period of settlement of the grassland area.

The Trapper-Hunter

Early period. There was very little exploration and trapping south of the Arkansas River before 1800. North of this point, however, there was considerable trapping and hunting for skins earlier. As to the use of grassland animals other than bison by fur and hide seekers, there is very little early information. Noteworthy records are in the journals of Lewis and Clark[4] and of John C. Luttig.[5] They cover trips from St. Louis across the grasslands. Luttig went to a trading post which was established at the end of the journey up the Missouri River (1812–1813). Lewis and Clark crossed the entire grassland area in 1804–05. The first bison were recorded from southeast South Dakota; the prairie dog and badger were recorded from this area by both parties. There was no mention of the so-called plains grizzly bear in the vicinity of Fort Manuel or Fort Mandan in the central part of the Dakotas. The first mention of this animal by Lewis and Clark was in extreme western North Dakota. The principal furs traded were beaver, otter, muskrat and fox; the principal rough hides were bison, wolf, deer and elk. Since the bison hides constituted a large part of those traded, there was a sharp

[3] C. T. Vorhies and W. P. Taylor, Professional Paper; *U. S. Dept. Agr. Bull.*, 1091: 1–40. 1922.

[4] R. G. Thwaites, "The Original Journals of the Lewis and Clark Expedition, 1804–1806." Vols. 1–3. New York. 1905.

[5] J. C. Luttig, "Journal of a Fur-trading Expedition of the Upper Missouri, 1812–13." Ed. Stella M. Druman. Missouri Hist. Soc., St. Louis. 1920.

decline in the fur and hide business with the extirpation of the bison, which came soon after 1870. To what extent such species as the kit fox, spotted skunk and blackfooted ferret were utilized is not clear, though Woodhouse in 1854 mentions foxes in connection with the southern plains. Lewis and Clark mention trade in kit fox skins in eastern Montana.

The Cattle Period. During the cattle days, trapping continued as an important vocation on the plains. This is evidenced by the fact that Scotts Bluff (now a National Monument) was so designated for a sick trapper named Scott, who was left behind to die by a group of inconsiderate companions.

Relative to trapping, Colonel Richard Irving Dodge (1883) says:

> When I first came to the "Far West," thirty-two years ago, trapping was still an institution [about 1850]. Generally alone, sometimes in couples, rarely in more numerous companies, trappers ranged the whole country wherever peltries were to be had. . . . It is a common matter of wonder among persons ignorant of the ways of the Plains, how these men could have voluntarily adopted a means of livelihood apparently so full of danger. . . . Each, making his way to the village of Indians most convenient to the territory in which he wished to trap, proceeded to interview the chief whose friendship and protection were gained by generous presents. . . . Other presents purchased one or more squaws and a tepee. He thus became a member of the tribe.

THE STOCKMAN, COWBOY AND CROP FARMER ATTITUDE

Bison were no doubt slaughtered as competitors of the cattle, and 1876 saw the practical end of the bison herds and the Indian that lived by means of them. With the decline of the bison, there was a definite decline of the wolf due to poisoning, which also killed off the kit fox.

In referring to the badger in his study of the mammals of Texas, writing in 1905, Bailey[6] says:

> The cowboys have a real grievance against the badgers, especially those who have been thrown from running horses that had inadvertently stepped in old and half-concealed holes. Such accidents are by no means rare and sometimes they are fatal to both horse and rider. It is hardly surprising, therefore, that the cowboys look upon the badger as a legitimate target for their six-shooters. In a prairie-dog country, however, this is not a fair excuse, for prairie-dog holes are just as dangerous, and each badger helps to reduce the total number of pitfalls.
>
> The rapid increase in the abundance of prairie dogs in certain parts of the State and their constant extension of range is unquestionably due in great measure, if not mainly, to the destruction of badgers.

The consideration of any possible *use* for flesh-eating animals such as the coyote, kit fox and members of the weasel family, including the large burrowing badger, never occurred to ranchers or cattlemen. Bailey has described his experience with certain Texas ranchers at whose request he killed a badger as follows:

> The people had no reason to believe that he (the badger) had ever killed any of their poultry, but they were afraid he would. There were already two badger skins hanging in the tool house on this ranch, while a twenty-acre field of alfalfa was rendered almost worthless by prairie dogs. When I tried to convince the owners that every badger on the ranch was worth $100 to them they only laughed. Some of the ranchmen, however, appreciate the services of the animal, but even then the temptation to try a shot at one at long range or to let the dogs catch one for a fight is often too great to be resisted. Dead badgers are frequently seen by the roadside with smashed skulls or bullet holes through them, and this most often in the heart of the prairie-dog country. When taken to task for their folly in destroying these valuable animals the ranchmen have usually stoutly denied the charge, saying that most of them were killed by emigrants and other "tenderfeet."

Foxes had always been destroyed by agriculturalists in Europe and the eastern states and consequently, anything that looked like a fox, even a small one, was thought dangerous to livestock anl poultry. The badger, particularly, "surely must have invaded the poultry

[6] Vernon Bailey, "Biological Survey of Texas," N. A. Fauna, 25: 1–222, 1905.

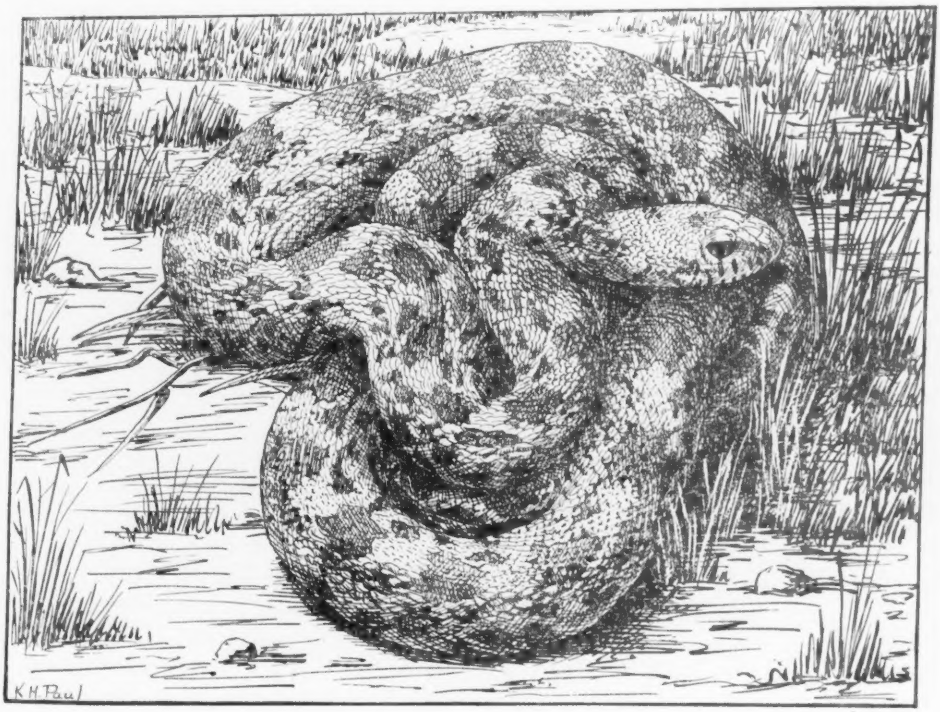
house"—and the ferret and weasel likewise. The destruction of the enemies of the rodents in the grassland went on to a greater degree than it does in the forested areas even to-day. The prejudiced methods were followed without question.

The stockmen felt the increasing losses resulting from their depletion of grass forage, which began before 1890 and from time to time redoubled their long-standing efforts to control carnivorous mammals in the western plains and mountain foothills, chiefly by the use of poison. This involved the destruction of wolves, coyotes and all other animals which will eat poisoned flesh. This was due to their alleged destruction of livestock and game.

Evidence is accumulating that certain rodents increase in numbers under overgrazing and damage grass and cultivated crops in a serious manner. It is the opinion of students of grasshoppers that overgrazing is a cause of outbreaks.

With overgrazing and the destruction of their enemies the rodents of the grassland, particularly ground squirrels, prairie dogs, kangaroo rats and jack rabbits, constitute a problem in grazing areas as competitors of livestock. Their increases on the plains, following settlement, are well described by Merriam in the 1901 Yearbook of the Department of Agriculture:

> On many parts of the plains prairie dogs were more abundant in 1900 than formerly and their colonies had overspread extensive areas previously unoccupied. This is due to the aid of the settlers (1) by decreasing the animal's natural enemies, and (2) to a minor extent by increasing the food supply. The settler waged warfare against the coyotes, badgers, hawks, owls, snakes, and other predatory animals which



Redrawn, Courtesy The Macmillan Company

BULL SNAKE—RODENT DESTROYER

ONE SIXTY-FOUR-INCH PACIFIC BULL SNAKE ATE FOUR FULL-GROWN GOPHERS IN ONE MEAL.

previously held the prairie dogs in check. The prairie dogs had multiplied until they had become a pernicious enemy to agriculture.

For example, one South Dakota settler stated that about 1885 his children noticed two or three burrows about a mile from his house, and in 1900 they had spread over and occupied a full quarter section (160 acres), having surrounded his house and taken possession of all the land near it.

The damage done by prairie dogs results in the loss of grass eaten and buried under the mounds.

Merriam cites many examples of losses. A cattle ranch had its carrying capacity cut from 1,000 cattle to 500 by an increase of prairie dogs which extended to cover 300 square miles. In the same area there was a decrease in population and the abandonment of a post office.

Merriam advocated the use of poison to control the rodents, and it was only two or three years after the publication of Merriam's suggestion (1901) of the use of poison that Dr. D. E. Lantz, of Kansas Agricultural Experiment Station, bought more than a ton of strychnine to poison jack rabbits and prairie dogs. It was the rare fortune of the writer to accompany him in May, 1904, when he checked over the decisive results of his strychnine campaign of the preceding summer. Prairie dogs were reduced almost to extinction in the areas where the poison was applied. Enough, however, are practically always left to make a "come-back."

The discussion by Merriam (1901) indicates that the *reverse* of biological control is a fact: "The prairie dog and ground squirrels have several mortal enemies which, when not interfered with by man, usually served to hold their numbers in check. The most important of these were the coyote, badger, black-footed ferret, bull snake and rattlesnake [the last of which the stockmen could not be expected to encourage]. Their methods of attack differ widely (see figures).

The coyote sneaks up to the border of a prairie dog colony or ground squirrel burrow, hiding behind straggling tufts of vegetation. He lies in wait until some unwary rodent comes out to feed, when by a quick rush it may be headed off and caught. The kit fox proceeded in a similar manner. The badger, however, drives his prey into its burrow and then digs it out. His foreclaws are long and strong. [In 1928 Silver reported observations showing the efficiency of the badger in the control of the prairie dog.] The black-footed ferret is built like a weasel, and though much larger, is small enough to enter and traverse freely the burrows of prairie dogs, so that he is able to pursue them to the ends of their holes and capture them with absolute certainty. He is, therefore, one of their most relentless and terrible enemies, and if sufficiently abundant would quickly exterminate all the inhabitants of the largest colonies.

The bull snake (*Pituophis sayi* Schleg.) and the Pacific bull snake or gopher snake (*P. catenifer* varieties) are enemies of ground squirrels. Guthrie[7] says: "One Iowan caught bull snakes and put them in a field that was heavily infested with striped ground squirrels. They completely cleared it of the rodents." The Pacific bull snake is also important as a rodent destroyer. Van-Denburgh[8] (1922) says: "The snake is introduced into the burrow of the rodent and disappears. In a few hours he reappears, languidly crawling into the sunshine, while a huge bulge about two-thirds the way along his mottled body gives proof of what has happened down in the dark underground galleries. One sixty-four-inch Pacific bull snake that was brought to me was handled too much; he vomited four full-grown gophers, none of which was more than slightly digested. On another occasion more than a dozen mice had been swallowed." Nevertheless, the snakes are commonly killed on sight and are easy to see. Mammalogists belittle the effect of the snake, but those who have cared for them in exhibition collections hardly

[7] J. E. Guthrie, *Ia. Agr. Exp. Sta. Bull.* 239: 146–192, 1926.

[8] J. Van Denburg, "Reptiles of Western America." Occ. Pub. Cal. Acad. Sci. 10: 2; 623–1028.

agree. Mr. Bertrand Wright states that a bull snake will eat a Norway rat every five days when confined where but little exercise is permitted. Mr. F. X. Leuth, of the Illinois Natural History Survey, states that the maximum rodent consumption by a bull snake in captivity was seven mice in one day and fourteen mice in one week. This applies to snakes kept inactive and in a relatively cool place.

It is evident from all the literature available that the ferret, kit fox and bull snake are in no way injurious to agriculture and also completely harmless to the grazing interests. The badger does very little damage and a large amount of good. The same is true of other members of the weasel family. Murie[9] has recently shown that the coyote is a beneficial animal in Yellowstone National Park. Likewise, Olson[10] has presented arguments to the effect that the large wolf is a benefit to game and to the forest trees in the Superior National Forest.

Two questions remain: (1) What has been done in the way of biological control of mammals? (2) What can be done to try it out, and what resources are available with which to make the experiments?

As to what has been done—it is only in the past fifteen years that managers of large game reserves have learned that there is something to be done besides killing off alleged undesirable animals and protecting popular ones. Many grazing or range managers have failed to make even that much progress.

In 1936 Vorhies[11] made the following general statement:

> There has been, on some of the erosion projects, a tendency to damn, convict and sentence the rodents to death on a large scale on areas to be worked for erosion control. . . . Surely in an area in which burrowing rodents are so important in the loosening up and aeration of the soil—as in our earthwormless, arid southwest—the little animals deserve to have the possible benefits they confer on the soil carefully balanced against the possible effects of increasing erosion. It may be fairly questioned whether rodents, by and large, are important in causing erosion directly.

He finds that the cost of rodent control is not justified by the benefits, if any, that are received. It is an established fact that under certain conditions, at least, rodents may be more helpful than injurious to man's interests because of their largely beneficial influence on the soil, their serving as a food supply for valuable fur-bearers, and their insectivorous habits.

It is, accordingly, obvious that very little in the way of developing biological control on areas where it might be tried has been accomplished.

During the early part of the poison period, apparently there was no thought of any other method being practicable. In recent years, however, some evidently casual observations have been made by the Biological Survey, and the following is a quotation from a personal communication:

> There are numerous instances where predators, such as the coyote, have remained unmolested and yet the ground squirrel, prairie dog, and jack rabbit problems on these areas have been alarmingly acute. There are areas where rodent populations have been reduced by artificial means almost to the vanishing point and yet, despite the fact that native predators were left alone, the recovery of the rodent population was rapid.

The lines appear to refer to general observations instead of the kind of long-time experiments on land devoted primarily to research that would lead to definite results. The observations made since 1916 could hardly have included more than a third to a half of the original predator species. The populations of such as remain are reduced almost be-

[9] A. Murie, "Ecology of the Coyote in the Yellowstone Fauna of the National Parks of the U. S." *Bull.* 4: 1–206, 1940.

[10] S. F. Olson, SCIENTIFIC MONTHLY, 46: 323–336, 1938.

[11] C. T. Vorhies, "Wildlife Aspects of Range Rehabilitation. Hoofs and Horns," N. 5, No. 8: 6–7; N. 5, No. 9: 10–11.

yond recovery. The kit fox, blackfooted ferret, badger and certain snakes are depleted almost beyond recovery in many localities and the first especially is rapidly disappearing due to the poisoning of coyotes in areas where they are still present. The U. S. Biological Survey, during this period of increasing control of mammals from 1916 to 1931, probably had ten to twenty mammal destroyers to every scientific investigator. During this period, poisoning of mammals was possibly looked upon as a means of building up a strong bureau, comparable to the one in charge of insect control.

Status of the Small Predators. As to the resources available, beginning on the northern plains, Jackson, reporting on the mammals of Manitoba, stated in 1926 that the badger population on the grassland portion of the province in 1905 was estimated at 20,000—ten per square mile in some places:

> But cultivation, destruction of gophers, trapping, and poison have reduced the annual catch to 1,000 or so. Badger hair is worth eighty-five dollars a pound, and used in making the best shaving brushes and in faking silver fox by anchoring in white badger hairs, and sold as "pointed fox."

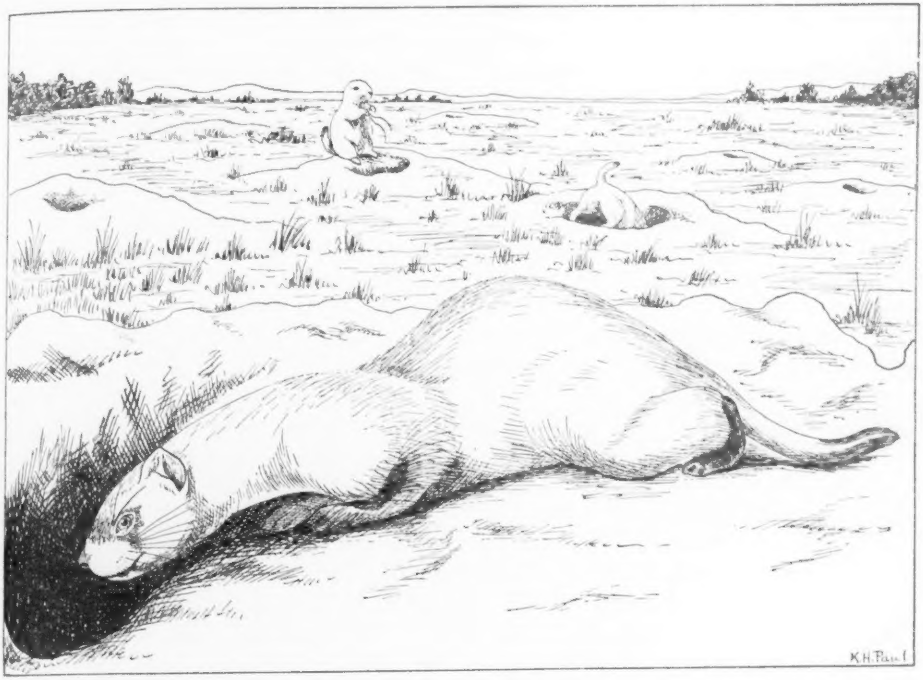
The other prairie provinces have a similar history in this respect. North Dakota licenses the trapping of coyotes, skunks, badgers, weasels and foxes. Wm. J. Lowe, Fish and Game Commission, states that there have been no records of kit fox for some years. A blackfooted ferret was taken in the state in 1935. South Dakota appears to regard the badger as a predatory animal. There trapper wardens instruct men and boys in predator control. The Nebraska Game, Forestation and Park Commission express the view that the kit fox and blackfooted ferret do not occur in that state. Dr. C. D. Bunker, of the University of Kansas Museum, states on the authority of a man associated with the buffalo slaughter that the kit fox was generally destroyed by poison put on buffalo carcasses by cattlemen during the period of buffalo slaughter, 1870–75. One or two blackfooted ferret records in Hamilton County in the western part of the state have come to the Kansas Museum in recent years. In Oklahoma, the badger is uncommon; the kit fox and blackfooted ferret are almost unknown now, but the fox was mentioned by early travelers. The Texas Game Commission reports show considerable numbers of badgers trapped each year. It is evident that there is still considerable farmer trapping which has served to bring about and indicate a very low population of badgers, blackfooted ferrets, and especially kit foxes in cultivable areas. These animals have evidently almost disappeared from cultivated and intensively grazed areas.

However, in the grassland area of Utah and Nevada the kit fox is still reported. Badgers are said to be abundant in some places in central Wyoming and also in Alberta.

Given the necessary land—an area of somewhat more than a million acres fit only for grazing—the animals most highly desirable to restore may exist in greatly reduced numbers. A population develops under protection or can in all probability be restored by transplantation. Such an area should be managed on a hands-off basis and can serve as a place to preserve the great plains big game in a wild state.

One who makes a brief study of the Great Plains big game reserves is likely to be impressed with the fact that the bison and antelope are rapidly being domesticated in all of them due to (1) winter feeding on hay, and driving to winter ranges; and (2) various schemes for regulating breeding and care of young in close quarters.

The reserves are at the same time usually overgrazed to a considerable



BLACKFOOTED FERRET OFTEN FOUND ASSOCIATED WITH PRAIRIE DOGS

THE FERRET, BUILT LIKE A WEASEL, IS SMALL ENOUGH TO CATCH PRAIRIE DOGS IN THEIR BURROWS. FERRETS HAVE ALMOST DISAPPEARED FROM THE GREAT PLAINS.

degree. One of the largest of these, formerly at Wainwright, Alberta, is very badly overgrazed (personal observations, 1939). Here the smaller animals are accordingly deprived of shelter and are wanting or deficient in numbers. Some of them, as the badger, certain smaller vertebrates and various invertebrates were threatened with extirpation. Future generations have a right to see these animals in a wild state. There would be many distressing appeals from botanists if redwoods, beech and giant cedars and other trees with their associated shrubs and herbs were rapidly coming under cultivation as nursery stock, and from bird lovers if several song birds were becoming extinct (see Shelford).[12]

[12] V. E. Shelford, *Science*, 90: 564–565, 1939; *Science*, 90: 591–592, 1939; *Can. Field Nat.*, 54: 5–7, 1940; *Science*, 91: 167–168, 1940.

Research on Plants and Animals

The scientific study of grassland problems of native grasses and especially of animals was long neglected. Down to 40 or 50 years ago, evidently the idea that anything could be learned through the study of grasses had scarcely entered the mind of even scientifically trained people, and the study of animals lagged 35 years behind that of the grasses. An illustration of this point may be seen in the following quotation from Chapline and Campbell[13]: "Range entomology and other special phases of zoological research may be justified where high economic values are at stake. Cases in point include the beet leafhopper and

[13] W. R. Chapline and R. S. Campbell, Research and extension program. In "The Western Range," 74th Congress, Second Session, Senate Document 199, pp. 523–533, 1936.

locust infestations in many parts of the West, where the pests breed chiefly on overgrazed range lands and often migrate to nearby irrigated areas, thus causing great damage both to the range forage and cultivated crops." Such works as that of Wolcott,[14] writing in 1937, to the effect that insects under certain conditions eat more grass in pastures than cattle do indicates the importance of research on plant and animal communities by trained individuals.

Previous to the recent drought and depression, from which recovery is far from complete, there were only two or three range experiment stations in the large climatic grassland areas. When the drought and depression called for scientific study, agronomists quite unprepared to cope with the native grass problems were much in evidence.

That there is a need for a grassland area for use in the study of the original balance in nature on the plains, as a scientific project, is apparent. It should be comparable in size to one of the larger National Forests of which there are approximately 150, more than a third of which exceed a million acres in area. It can at the same time preserve the large ungulates in a wild state and depict the conditions of the covered wagon days.

Grassland offers many advantages over other types. Some of these are:

(1) Grassland allows full visibility of the more important larger animals and plants.

(2) Niches and hiding places for animals, such as tree tops, fallen and hollow trees, and dense thickets do not occur in Great Plains areas to retard observation.

(3) The life histories and life span of the principal plants is about one-tenth that of forest trees and this greatly facilitates observation because of the more rapid turnover and hence the quicker response to climatic fluctuations.

(4) The grassland flora and fauna have intimate relations to the general problems of agriculture and human welfare on the Great Plains.

(5) Grassland constitutes about 40 per cent. of the original vegetation of the earth's land surface and is of great importance to mankind in general.

(6) It has been much less studied than forest.

(7) Stable primeval areas or semi-primeval areas of large size are rapidly disappearing. In another generation the program proposed by biological scientists may perhaps be impracticable.

(8) The field is unencumbered by organized pure science research projects.

(9) It is a vegetation type in which ecological interest is great and much important plant ecological work has been done on the moist eastern portion of the plain but all animal relations and their interactions with plants have been neglected.

(10) The problems of wind and water erosion of soil and the attendant dust movement are essentially biological problems.

(11) Suitable lands are of *low* economic value.

(12) Its climate is suitable for the work of investigators.

A grassland laboratory possesses facilities for research not available in some other types of land, such as forest or agricultural land. The great complication of forest vegetation makes many types of shelter and many niches affording protection from the elements to animals and smaller plants, which render observations difficult. Tundra shares the advantages of grassland for researches involving field observations. These barren lands, however, are in a climate forbidding to continued scientific research and are remote from academic centers.

The plans of interested scientists have called for an undisturbed check area which could be under observation for a

[14] G. N. Wolcott, *Ecol. Monographs*, 7: 1–90, 1937.

sufficiently long period to permit an analysis of drouths and dust storms and rodent, predator and grasshopper outbreaks that occur at rather long intervals of 30 to 50 years or more.

Agricultural lands are subject to such erratic overturn that causes of cyclic phenomena can not ordinarily be followed in a scientific manner. Game preserves and other small areas are, necessarily or unnecessarily, so managed as to obscure natural phenomena and render scientific conclusions unavailable or uncertain. Students of grasshopper outbreaks and, to a lesser extent, infestations of rodents, desire large areas to follow the normal population of these pest animals. The need of a large area of approximately 1,000,000 acres has been voiced by many, including grasshopper specialists, whose scientific results require freedom from *marginal effects* in this migratory group. For example, a tract or a few dozen sections of land surrounded by cultivated and overgrazed areas is so completely sprinkled with wind-borne organisms as to render conclusion as to natural trends uncertain.

Recently there have been efforts on the part of the Ecological Society of America, the National Research Council and the National Park Service to have an area set aside large enough to contribute to all these objects. Other reasons for this have been set forth by Hanson and Vorhies[15] in the March, 1938, number of this magazine and another by Cahalane in the August, 1940, number.

[15] H. S. Hanson and C. T. Vorhies, Scientific Monthly, 46: 230–241, 1938.

Summary and Conclusions Relative to the Grassland of the Great Plains of North America

I. The evidences reviewed, including the historical facts, indicate the following:
   1. Biological control of pest mammals has never been tried.
   2. The essential species are still available but greatly reduced and declining so that a point of extinction may be reached reasonably soon.
   3. The several tracts of land of suitable size and present use are available at low cost. A part of each is already publicly owned.
   4. The value of rodents as soil builders renders retention of natural populations under biological control in the best interest of soil fertility and the production of grasses.
   5. The restoration of the plains fauna on a large tract is desirable from the standpoint of its preservation in a wild state.
   6. A large reserve is needed as a check for lands under management. Such a tract can form a basis for an adjacent biological laboratory for the study of bioecological problems, evolution, hormones in nature, the origin of pest populations, etc.

FOOD HABITS OF PRIMITIVE MAN

I. FOOD AND THE CULTURE PATTERN

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The Problem

Our understanding of human nature and motivation has been, and to a large degree still is, almost entirely under the influence of the theory of economic determinism. This theory, together with the aftermath of behaviorism and the crude interpretation of the struggle for existence before genetics revealed the complexities of natural selection, have led to a most oversimplified picture of human conduct. Man was viewed as merely an animal driven by biological forces, dominated by self-interest, *i.e.*, what we think self-interest should be, and generally striving to survive by satisfying his biological urges in a direct and simple fashion. This characterization of man rings so true and seems so reasonable that at first glance students of biology, especially if unacquainted with anthropology, will find nothing wrong with it and wonder why any one should question its validity.

Under the influence of nineteenth century thought it was taken for granted that every primitive custom was generated by a utilitarian cause of a kind we choose to call rational. Satisfactory evidence for the accuracy of such causation could, by the very nature of the case, seldom be presented, but the appeal of this belief pattern was so strong as to make its assumptions go largely unchallenged. It is a fact, however, that current anthropology presents us with a vast store of material proving that primitive man, like his modern brother, invariably acts through the intervention of beliefs, and that these are not always generated by necessity, but on the contrary, may determine what precisely constitutes necessity. In addition, man does, more often than not, go contrary to biology and inflicts pain upon himself and even courts death if some cherished belief dictates that he do so. He may reject good food or even fast for long periods if he thinks it pleasing to some spirit or if he views it as "necessary" for some remote goal, or for no good reason at all. Out of many possibilities he may select a diet that produces a deficiency or inflicts considerable discomfort. Although many wish to explain away these so-called superstitions and irrationalities of the past, as though our modern diet does not have its own "superstitions" and "irrationalities," the fact remains that they exist, and even persist, that they are deep-seated in all human cultures and are as much a part of man's conduct as the family, art or loyalty of some sort. Since they exist they must be studied and understood.

The Scientific Approach to a Prejudice

Scientists do not display exceptional attitudes toward new ideas. Like the vast majority of human beings they find the old and established so comfortable and so wholly consistent with other unquestioned beliefs as to regard it as reasonable. The new, and as yet unassimilated is then necessarily declared to be unreasonable. The following questions were submitted to several hundred trained scientists and to as many laymen. Both groups gave only "reasonable" answers. The questions were: Why did man domesticate the cow? For what

purpose was the chicken first domesticated in Burma? Omitting the Biblical account, how did the day of Sabbath originate? Why were Eskimo women locked indoors during a whale hunt? Why do Jews, Mohammedans, Hindus, some Australian tribes, Micronesians and other groups proscribe pork? Why do Indians forbid the use of beef? Or generally state the reason for any particular dietary taboo or custom.

Few of the scientists questioned were especially familiar with the facts involved in each problem, and fewer still thought that knowledge of such facts was essential. Most of them relied, as a rule, on their reason and when they did so gave invariably the wrong answers. Since the chances are that the average reader will also supply the same answers there is no need stating those given. We shall indicate instead why they are wrong.

The cow was domesticated in Egypt and was originally used neither for meat nor milk nor as beast of burden. Our awareness of the present role of this animal is so fully taken for granted as to blot out all desire to know the facts, thus leading us into false reasoning about the original motive. "Primitive man began to keep animals not with an eye to profit but for the uneconomic though quite human reason that he jolly well liked to have them about as companions and for entertainment," says R. H. Lowie. One may even go further and say that the first domesticated animal, the dog, was not really domesticated by man. On the contrary, it was the dog that domesticated man. Early excavations show canine bones some distance from human camp-fires, indicating that he lived near human sites as scavenger. Later ones show remnants of man and dog together. Presumably, by loitering long enough near human camps the dog taught man conviviality with animals.

The fact of the matter is that man domesticated every animal he could lay his hands on, but discarded those that proved unamenable as pets. To quote from the same author:

> Pet-rearing ultimately gave way to exploitation because man is not a total abstainer from common sense if he indulges with fanatical moderation. He noted that the animals he sheltered from the struggle for existence came to differ from their wild brethren in point of size, hair, and other features. Some of these traits he prized as desirable and bred for. Thus trends that set in under the novel conditions were intensified: wooly and fat-tailed sheep, milch cows, egg-layers sprang into being. But this utilitarian frame of mind came last not first.

From Egypt the culture element of the cow diffused to India. There the cow is still a sacred animal, though when India adopted the cow, milking had already become a custom and came with it. China received the cow before dairy products had been developed but used the animal for beef. In Africa, where cultures abound to-day which sanctify the cow and have milk and dairy products as their staple food, beef, too, is eaten, though exclusively on ceremonial occasions and at that by the wealthy only. Much of East Africa subsists on agriculture, "but," writes Melville J. Herskovits, "the number of cattle owned by a man correlates highly with his position, for position here, as in most societies, is related to wealth, and cattle are the sole expression of wealth. It is of no consequence how much cultivated land or other goods a man possesses, for should he not have adequate resources in cattle he can have no place among the wealthy. . . . Cattle are eaten only on certain ceremonial occasions, or when an animal dies, nor have they any other utility aside from that of supplying milk, since they are never employed as beasts of burden." As we shall see in all these cultures, man's relations to the cow, to her milk and to the process of milking were weighted down with severest ritual.

Chinese sources indicate that the chicken was first domesticated in Burma, where it was used for purposes of divination. A bamboo splint was inserted into

the perforation of the femur and by the angle of inclination one peered into the future.

Cockfights were popular in Burma. To settle disputes a cockfight was arranged, and the owner of the winner was adjudged right. Even to-day the Wahuma of East Africa and other tribes single out chicken meat for special contempt, regard eggs as feces and prescribe purgatives and segregations for any one who eats them even by mistake. Yet each family of any consequence raises poultry and not for fun or sport but to satisfy a potent and time-honored need. Chickens are dissected, their entrails exposed and from their convolutions all that the future holds in store for the individual or the community is deciphered. While most of us do not display this unquenchable anxiety about the future, with primitive man it was an obsession. Whatever phenomenon showed variation was exploited for divination. Stars, comets, eclipses, hands, figures on the ground, shapes, the flow of water, the flight of birds, facial muscles, dreams, bones, entrails, fires, clouds, leaves, plants and what not.

It should be noted parenthetically that while these acts of divination brought man in contact with specific bones and their intimate structures, for example, foramina, these led to no development of anatomical or physiological knowledge. This fact brings to mind a similar situation in Egypt, where embalming meant some familiarity with human anatomy. The Egyptian priests and medicine men developed expert embalming methods but not a trace of a science of anatomy.

Speaking of the domestication of the fowl can not but bring to mind the case of the turkey. It was the only domesticated North American animal, excluding the dog. The Hopi of Arizona were one of the few tribes that raised it but not at all for food. They kept it for its feathers. The Aztecs, however, used the turkey both for its meat as well as feathers and also ate the dog, which the Hopi did not. Both tribes were mainly agricultural.

The answer to the next question the reader may find in any anthropological text. Suffice it to say here that rest days in general were introduced as acts of mourning or fear, as sit-down strikes against an unfavorable fate rather than as rest from hard labor. Continuing with the questionnaire and dealing with those questions which have a direct bearing on food we come to the fourth which is answered by the following quotation from a work by Peter Freuchen:

> There are a number of native superstitions about whale hunting as there are about everything. From olden times there has been a gentleman's agreement between men and whales that no woman should be present at the hunting. This resulted from a legend that at one time a woman harpooned a whale and thereby insulted all whalekind and kept them away for many years. When I was in Hudson Bay an old angakok had revived the tradition, and no woman was even permitted to be outside her tent while the men were hunting whales. I saw them disappear when we set out. Only old ladies past the age of fertility (and therefore regarded as men) could run about from tent to tent relating what was happening out at sea.

The remaining questions deal with dietary taboos and these constitute a problem in themselves. Before considering them, however, let us point out that the scientist who has not devoted time to a special study of each specific taboo will invariably follow the folklore of our time and attribute a modern cause to its origin. In other words the scientist like the layman will be governed by a dominant belief or theory and tend to explain away precisely those aspects of reality which need study. Both are convinced that their explanations are based on reason and both will condemn the mustering of contrary facts as befuddling and petty quibbling. This mode of approach may justly be termed superstition or magic. The scientist who argues that domestication followed consciousness of

need and was utilitarian in origin, or that taboos stem from practical motives simply speaks from ignorance of primitive man. As in the superstitions of the past, forces and causes are postulated that do not exist but are believed to be real with a show of logic and reason. The method of science demands different procedures.

The Tyranny of Belief over Diet

Primitive man lived his life within his culture pattern very much as we do. To judge him at all is bad enough but to judge him by our standards is unadulterated folly. Just as we are guided by our beliefs, values and assumptions, so did he use his reason and followed his daily pursuits on the basis of his beliefs, his values and his assumptions. His values were, of course, different from ours and he tended to question or challenge them far less than we do. More particularly, in ignorance of the method of science which constitutes a mighty weapon in our life and thought, he failed to employ and improve his mode of approach, as we constantly strive to do, and was left at the mercy of uncorrected groping and blundering.

Regarding food, all primitive cultures displayed one common peculiarity still present to a significant extent in our own scientific era. Primitive man enveloped his diet, his eating etiquette, cooking and all functions pertaining to food, in a network of habits and regulations, theories and fears, obligations and ritual. These were strong enough to exert a powerful influence over his respective culture pattern for thousands of years. The dietary prescriptions of the Bible may serve as a familiar illustration. All animals with uncleft hoofs and not ruminating were declared taboo and impure. So were fish without fins and scales, all worms, crustacea, molluscs and most birds. No argument relating to the evil quality of the forbidden food is given or to the nature of its effects upon health. It is merely stated that "they shall be an abomination unto you," and are "unclean." The text continues:

> All fowls that creep, going upon all four, shall be an abomination unto you. Yet these may ye eat of every flying creeping thing that goeth upon all fours which have legs above their feet, to leap withal upon the earth . . . the locust after his kind, and the bald locust, and the beetle after his kind, and the grasshopper after his kind.

Particular stress is laid upon the admonition, "Thou shalt not seethe a kid in its mother's milk," since we find it mentioned three times in the Pentateuch. There seems to be weighty evidence besides, presented first by J. G. Frazer, that it was one of the original ten commandments.

Equally interesting and representative are the dietary rules of India. Here too proscribed food is considered "unclean" and "an abomination," and dietary notions are inextricably merged with the problem of caste. Thus a Brahmin regards as polluted all water or food touched by any one not in his own caste, hence inferior to him. Even the shadow of a lower casteman falling upon food renders it polluted and uneatable. Madras Brahmins regard food as polluted which had merely met the gaze of a lower casteman. Not only is such food considered unclean, but it must not even be thrown away lest others eat it and suffer unconscious pollution.

The role that food plays in the caste system can be seen from the following:

> Where a certain caste can not eat food cooked by another caste, while the latter permits food to be eaten which was cooked by the first caste then the first caste is superior to the second. . . . If a Brahmin accepts water from another caste that caste is considered clean in Bengal. If he accepts food cooked in oil, then the caste is still better. . . . Clean castes do not pollute water; but below them are castes which pollute water; below them are . . . castes which pollute an earthen vessel, then castes which pollute a brass vessel.

Moreover, food is a significant factor in caste degradation. Some castes are

degraded by eating meat, by drinking wine or smoking tobacco. Consumption of pork, beef and fowl are considered wholly degrading to most castes.

The taboo of intermarriage is sufficiently real to us within our own culture in so far as it affects members of the white and Negro races. To Hindus it is made a thousand times more real since its prohibitions involve individuals of different castes, of which there are over three thousand. Equally real to Hinduism is the taboo of interdining. This term describes the rare event in which two members of different castes defy custom and eat together. So important is the act of eating that interdining between members of castes not even far apart in status, leads to a family tragedy of equal possibilities and dimensions as may intermarriage in our society.

Central and Eastern Africa are mainly populated by Bantu tribes. Many of these are non-agricultural and have milk as their staple food. Cattle is venerated by almost all cultures though there are few indeed that eat beef at all, and these do so only on rare occasions. All work relating to dairying and care of cows is performed by men. It is a heinous crime for a woman to come near a cow or be near the kraal at milking time, or touch a vessel containing milk or even touch a man who is about to milk or has just finished milking. Women's main tasks are washing the earthenware milk pots with cows' urine, and churning to make butter. The latter is quite an industry, though butter is used little as food but chiefly for anointing the body.

Only "chiefs and wealthy men add beef to their milk diet," and that only on rare occasions. "Usually the night intervenes after a meal of beef and beer (which must follow beef) before milk is again drunk. There is a firm belief that the cows would sicken should milk and meat or vegetable mix in the stomach." Vegetables are seldom eaten, in fact only in times of extreme milk shortage "when pressed by hunger. . . . During her menses a woman may not drink milk, except from an old cow past bearing; should her husband fail to procure such a cow she eats vegetables until she is well again." This prohibition too is rationalized by the claim that it would be injurious to the cow.

Milk must be drunk fresh and never boiled, "as the boiling would endanger the health of the herd and might cause some of the cows to die." For the same reason "the meat of goats, sheep, fowls and all kinds of fish is deemed bad and is absolutely forbidden to any member of the tribe" (The Banyankole).

In most, if not all pastoral tribes, "cultivation of the ground is regarded as injurious to their cattle" and all manual work as degrading. This contempt for agriculture is reminiscent of the Biblical attitude toward Cain. It also finds ample expression in the Iliad. But be the tribe agricultural or pastoral, cattle is everywhere virtually holy. Among agricultural tribes "the principal use of cows is to obtain wives." "Cattle are money among the Wanyika and they prefer to save their cattle to barter for a higher order of chattel (in their eyes)—women." "They give more care to a sick calf than to a sick wife," continues the author, L. J. Vanden Bergh. "Barring the absence of a roof, the enclosures sheltering the cows are better built than their own huts." As a rule the eating of meat is not prohibited but is too much of a luxury. Only chiefs whose rank varies with the number of cattle they possess can afford it. Poorer people need their cows, goats or sheep to purchase wives or pay taxes. All meat when eaten must be roasted on a spit since it may not touch a pot. It is cut into small pieces "about two inches square" so that the chiefs, the only ones to eat meat, need not exert themselves in tearing or biting off pieces.

Cows yield only about five pints of milk daily and much of it is given to the

calf by command of ritual. A cow may not be milked until the calf has had its share and the udder must not be emptied since some milk must be left for the calf. Should the calf die, its skin is preserved and produced each time the cow is milked. In addition cow dung is put to many practical and spiritual purposes in building fires, religious ceremonies and medicines.

Since milk must not come in contact with beef or vegetables in man's stomach, so as not to bring certain death to the cattle, proper intervals are observed between the consumption of these items. After eating vegetables, some tribes, such as the meat-eating Masai, wait forty-eight hours until milk may be drunk. Beef, eaten only by chiefs, among most Bantus and at that on rare occasions, may be consumed only at night and must not come in contact with any milk vessels. No milk may be drunk until the next day. It should be noted that contemporary orthodox Jews still observe similar restrictions, the so-called kosher laws. After the consumption of meat no milk or cheese is permitted for six hours and two hours must elapse before meat may be tasted after milk. The two kinds of foods require two sets of dishes and tablecloths and even an unintentional error is regarded as a serious offense against God.

Women may not drink any milk at all during their entire period of menstruation unless they are rich enough to have cows that are definitely past bearing. At that such milk must be kept apart and may be used exclusively for menstruating women. Women in childbirth are allowed to drink milk only if the baby is a girl. If it is a boy then the mother may drink milk from a cow that had lost her calf. Under no circumstances may milk be boiled or warmed, kept near a fire or brought in contact with metal. In passing it should be noted that while some tribes, *e.g.*, the Baganda, never drink milk fresh but clotted, others make use of it in all forms while still others drink it only fresh. The prohibition of boiling seems widespread and also the admonition to keep milk away from metal vessels or objects. In this connection it may be noted that with the Hottentots the system is reversed. Women do the milking and men concern themselves little with the cattle. In the summer the tribe subsists almost exclusively on milk, yet men are forbidden to taste sheep's milk. The death of a cow is a major family tragedy foreboding evil and often leading to the owner's suicide. Tonics and medicines for cows are far more highly developed than for humans and native religions provide more gods to care for the requirement of cattle, their health longevity and fertility than for the needs of men.

Practically all Bantu cultures permit beef of animals that died a natural death. Usually it was the only beef they ever could eat. Not so the laws of the Bible. "Ye shall not eat of anything that dieth of itself; thou shalt give it unto the stranger that is in thy gates that he may eat it; or thou mayest sell it unto an alien: for thou art an holy people unto the Lord thy God. Thou shalt not seethe a kid in his mother's milk." Giving away prohibited food must be regarded as a great social boon. Many are the cultures that demand the casting away of all food left over after a meal. In many cases "No remaining food was kept or put aside for another meal." In addition, strangers among the Bantus must never be offered any milk lest it mix in their stomachs with vegetables or meat and thus afflict the cattle.

Whatever the practice, the reason given is always the same, the protection of the cattle. Boiling milk is bad not for the consumer but for the cattle. Should a menstruating woman drink milk the cow would surely become sterile. Among many Bantu tribes, *e.g.*, the

Banyoro, the belief prevails that it is immoral for any man or woman to till the soil or indulge in any agricultural work because such activities are injurious to the cattle. Bathing or even washing at all is prohibited on the ground that it would hurt the cattle. Among other tribes the woman is permitted to do agricultural work while the husband attends to the cattle and dairying. Other cattle-revering Bantu like the Baganda may "live entirely upon plantains and despise all other kinds of food." Everywhere, however, as in Biblical and Homeric times herding is highly regarded and agriculture is looked upon as degrading. Furthermore, the kraal must be provided with a perpetual sacred fire properly guarded. The cows must be milked in a definite order and in specific positions with regard to the fire. Generally speaking there are few acts involving cows or milk that are left unregulated but the peak is reached with respect to the royal herd.

The Banyoro king is revered by the people. He rules not over the land but over all the cattle. His major food is milk, though he may occasionally eat beef of an evening, never in the daytime. Under no circumstances may he eat vegetables or mutton. From his numerous cows a special herd is selected to supply him with milk. These cows are sacred and must not mingle with others. They are tended by a carefully chosen boy known as the "Caller" because "he had to call out to warn people to leave the path as he passed along with the cows." This boy was picked for the job when he was seven and kept it until he married. If he took sick and the royal physicians declared his illness critical he was strangled to save the cattle. The same fate was meted out to him if he became unchaste or had blood drawn by a prick or scratch. Those who struck or offended him were similarly treated.

All men employed to care for the cows had special titles, obeyed strict rules of chastity and could not wash with water but butter. The collection and transport of the king's milk, his way of drinking it, the handling of leftovers, the washing of the dishes, in a word, everything was surrounded with rules and taboos.

Serving the king beef was similarly regulated. He was not allowed to touch it with his hands and it had to be put into his mouth with wooden prongs. Meat could not be boiled in vessels but was roasted on wooden spits.

Courtship all over the land regardless of rank was conducted with cattle. To have status in the community a young man must acquire cattle and thus be in a position to woo his first wife. After the choice is made and the girl willing, her father begins a long process of bargaining and extracting as many herds of cattle from the young man as his wealth and his desire for the girl permit.

In spite of the fact that milk is so wide-spread a food throughout Africa, areas are nonetheless encountered in which a different attitude prevails. In parts of the Congo, milk was tabooed by all and regarded with great abhorrence. "Any one drinking it was considered unclean for several days and was not allowed to eat with his family. They could touch milk, for they milked our goats and sheep and carried it to us without suffering defilement, but it must not touch their lips. A boy of nine was known to have drunk some milky water out of a glass, and he was not permitted to eat with his family for five days. They could give no reason for this but only stated it was their custom." Incidentally, the very manner of drinking is of great import. This may be noted in the Biblical story of Gideon as well as in the Hindu custom of throwing water into one's mouth since lips must not touch the metal cup.

The ancient Egyptians, as was also noted by Herodotus, tabooed the flesh of

cows. Priests were allowed beef of steers but could taste no fish which they regarded as polluting. Beans were proscribed to all as was also pork which like the meat of many forbidden animals could be eaten ceremonially on certain holidays. Pork is still proscribed to hundreds of millions of human beings of the Hindu, Mohammedan and Jewish faiths and beef to some two hundred million Hindus.

In passing it should be noted that contemporary Jews are not permitted to eat the lower half of a cow and do not consider even the anterior half as kosher unless all major blood vessels are removed, since blood is considered a special "abomination." For meat to be kosher it must come from animals killed according to the ritual law. The same applies to the followers of Islam and the observation "some of them (Somali) died rather than take food which would have saved them because it had not been killed according to Mohammed and rites" speaks for hundreds of millions of men of many faiths.

(To be concluded)

THE FINEST SHOW ON EARTH

By Dr. EDWIN B. MATZKE

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If you were given the opportunity of viewing again one single scene from all those that you have enjoyed, that constitute memory's picture book of the past, which would you choose? Would it be one which portrayed the awe-inspiring grandeur of a total eclipse of the sun or possibly one which recorded the glowing, changing colors of an alpine sunset? Or would you turn to a page showing the brilliant patterns of a New England landscape when the days are growing short and your breath rises lazily before you? While a total eclipse and a sunset are passing fancies on the part of nature, lasting for moments or minutes at the most, autumn foliage in eastern North America clothes the hills in brilliant vestments for weeks at a time.

To what are these colors of autumn due? The ordinary cells of plants owe their green to two pigments, called "chlorophyll a" and "chlorophyll b." These can be extracted from the leaf with warm alcohol, and the solution becomes a deep rich green, a green that through long association with us on this earth has become soothing and restful to our eyes; no color seems quite so pleasing as that of chlorophyll, no color is so important, since only plants that contain this can manufacture foods, for themselves and for us. In addition to the two chlorophylls, two other pigments are also present in ordinary leaves; these vary from yellow to reddish orange. One of these, carotene, is common in carrots—a scientific justification, it has been suggested, that "carrots are good for the complexion." The yellow and orange pigments are less complex, chemically, than the green chlorophylls, and they are also more stable. When the weather gets cold in the fall, the green colors, which break down more easily, tend to disappear, and then the yellow and orange, which have been present all along but masked by the others, become visible. These are largely though not entirely responsible for the golden tints of autumn. These four pigments together constitute only a minute fraction of the fresh weight of the leaves—about twenty-six hundredths of one per cent.—a very small fraction when we

consider how important they are, especially the chlorophylls. There is another group of soluble yellow pigments which are not very significant in fall coloration.

Most striking of the colors of autumn are the reds. These are due to an entirely different group of substances, called the anthocyanins, compounds associated with sugars, dissolved in the cells of the leaves. These vary from the brightest scarlet through all the shades of red and magenta to the deep blues and purples found in some leaves and many flowers. Simple experiments show that the color of these substances depends partly upon the amount of acid present. If the center of a head of red cabbage, which is rich in these anthocyanin pigments, is cooked, and to the liquid obtained a little vinegar is added (vinegar is acetic acid), the juice of the cabbage will become bright red; if a little ammonia is poured in, the solution becomes blue to yellowish green. The greater the acidity, the deeper the red color will be.

Various factors are responsible for the development of these red and blue pigments. First there is the genetic makeup of the plant. Maples inherit the ability to manufacture these substances, while hickories do not; the petals of the buttercup are never red, while those of the scarlet sage rival the faces of the most highly embarrassed.

For the most part, light is important in the formation of the anthocyanins. The sunny side of an apple is brighter than the shady side; the "stem end" is more richly colored than the "flower end." Perhaps in days gone by you pasted your initials in opaque paper on green apples, and when the fruits ripened there were the letters in green on a background of red. The more modern version of this, as described by Arthur, is to paste Cellophane on a green apple, put India ink marks on the Cellophane, and then expose the apple to a suitable lamp; the skin of the apple shaded by the ink remains green. Photographic negatives have been printed on the skins of apples in shades of red and green, using sunlight as a light source.

It has long been known that red leaves of the Virginia creeper contain more sugars than green leaves on the same plant collected at the same time. In 1899 Overton put the leaves or leafy stems of various plants, such as some species of lily, of holly and of columbine, into sugar solutions, and after some weeks they became red. Injured branches of trees often become bright red, while the rest of the tree is still green, presumably because the sugars manufactured by the leaves are not transported away, and consequently stay where they are made. Abundance of sugars favors the development of the red pigments.

It is common knowledge that brisk weather—without prolonged frost—is conducive to rich coloration, and experimental work supports this general observation. Both with leaves and flowers this is true. A blue bellflower and a red primrose were pale, almost white, when grown under warm greenhouse conditions. Cool weather, though preferably not too frosty, stimulates colors in autumn leaves as well as in healthy youngsters.

Though abundant water favors the growth of plants, it does not result in brilliant coloration. Of course drought is fatal, but a degree of dryness toward the end of the season results in beautiful colors. Experimentally this can be shown by watering sparingly some plants that are "vulnerable," and by watering others lavishly; the former will have the red pigments more strikingly developed.

Although leaves rich in sugars are often brilliantly colored, plants growing in soil abundantly supplied with nitro-

gen are often just green. In general both leaves and flowers of northern plants are brightly colored, due to the strong light and low temperatures. However, in 1902, Wulff, collecting plants far above the arctic circle in Spitzbergen, found that in some areas visited by northern birds and fertilized by their excreta, which are rich in nitrogen, the plants were a healthy green, while the same species, growing in poor soil, were brightly colored. Anthocyanins develop best when the supply of nitrates is limited, even if the other conditions are favorable, suggesting, perhaps, that opulence and loveliness do not necessarily go together.

All these factors are important in the formation of these red-blue pigments, known as the anthocyanins. Normally they do not act separately, but through complex interrelationships, and there are exceptions to all of them. Although light is so important in the formation of these substances, the root of the beet, which develops in the dark, is rich in anthocyanins. But in dealing with living things there are always exceptions—little touches that make life worth while.

The drab brown colors of the late autumn, those of the sere if not the yellow leaf, result largely from still another group of substances, the tannins, or from compounds related to them. These are the same materials that are derived from the bark of certain trees, especially oak and hemlock, which are used in the tanning or hardening of leather. Tannins are almost universally present in the higher plants, though generally not in quantity sufficient to make their extraction practicable.

When the green pigments break down in the fall, the yellows which have been present all along become visible; simultaneously the reds and blues develop in certain plants so that various combinations and color effects are produced. After all these have disappeared, the brown remains—the brown that is destined to form a part of this good earth.

Most important of all our trees in producing the vivid colors of autumn, particularly in northeastern United States, is the sugar maple. Sometimes this is just yellow, but more often red pigment is developed, especially toward the tips of the branches, where the illumination is most effective. This tree is the one which is tapped in the spring, and from the sap maple syrup and maple sugar are obtained. It forms extensive groves, especially in New England, and is really the king pin in the coloration of the north. There is a brilliance to the red of the sugar maple that is unrivaled in any of our other trees—a brilliance that gives it an animation and almost a touch of light-heartedness that rather belies the temperament of the sturdy people with whom it shares the soil. In swampy areas similar effects are produced by the red maple, though it, too, may be just a bright yellow.

Associated with the sugar maple are the birches, especially the white birch. These are normally yellow in the fall, and it is common to see the gold of the birches and the red of the maples standing in sharp contrast to the dark green of the white pines and the hemlocks; such contrasts make the colors appear all the more striking. This is especially true in New England, where the "murmuring pines and the hemlocks" are so wide-spread. The aspen leaves also add their touch of flickering yellow, while the waxy barks of the white birches presage the snows that lie in store.

The rolling hills and ancient mountains of our northeastern states form a perfect setting, so that the trees for miles around may be seen at a glance—as if to make it easy for us to enjoy the sight. The hills and valleys and lakes and streams also offer a variety of conditions —of soil, of moisture and even of temperature, and so are important in pro-

ducing diversity and intensity of color in plants growing close together, even in plants of the same species.

South of New England the center of the stage is held not by the sugar maple, but by the oaks. The warm reds and reddish browns are furnished mostly by these trees. Each species of oak adds its own touch to the general pattern. By far the most brilliant is the scarlet oak, which amply justifies its name in the fall. Not a striking tree otherwise, the scarlet oak passes unnoticed until it takes on its cloak of autumn, and then it stands out like one whose modest virtues have been unappreciated. There is a whole galaxy of oaks in eastern North America, each of which typically ripens into a color that is largely its own. The white oak, whose staunch timbers have been used so extensively in shipbuilding, often has leaves red above and white underneath. When they blow in the breeze, the tree presents a curiously changing color pattern. Pin oak may assume an orange-brown color; chestnut oak becomes a bright yellow; black-jack oak may be brownish red, but more often is a glossy light brown, suggesting the leather of new riding boots; red oak passes from green to yellow to brown, while black oak soon becomes a dull brown. In spite of all these variations in the oaks, and in spite of the brilliance of their coloration, compared with the sugar maple there is a slight touch of the sombre in their effects.

While the maples and oaks form the theme of this symphony, the variations are provided by many of our other trees. Dogwood, white or pink at blossom time in the spring, is just as pleasing in the fall, with its red leaves and red fruits; and dogwoods are found from Maine to Florida and west to Texas. Along the banks of streams, and in low ground generally, the sour gum and sweet gum are often seen. These may also be red, or they may be clothed in royal purple. Sour gum is one of the first trees to turn in the fall—a harbinger of the great display to come. White ash may be yellow, or it is sometimes reddish or bluish purple. Sassafras, whose roots are sometimes brewed into a tea, especially in the spring, and served (under protest) to children, adds its tone of bright orange to the drier hillsides. Like the dogwood, it is widely distributed in eastern North America.

While these trees wield a giant brush of red and purple, others, such as the chestnut oak, are responsible for the brilliant yellow. Hickories, especially saplings, often show the touch of Midas. There are hillsides on which the tulip tree grows that look for all the world like the pot of gold at the end of the rainbow. The tulip tree is one of our oldest trees, geologically speaking. It has literally come down through the ages. In the Blue Ridge country it gets as much as two hundred feet in height and ten feet in diameter. Also adding its light yellow to the autumn landscape, especially in the haunts of man, is the Ginkgo, maidenhair tree of the Orient. With its fan-shaped leaves and exotic type of branching, it seems indeed like a tree of the Far East, especially to an occidental. It is known definitely only in cultivation, having come to us as a temple tree from China and Japan. Once found growing wild clear across the northern hemisphere, it has aptly been called a "living fossil," for it alone survives of an ancient group that has otherwise passed. Seward has suggested that each year, for a short time, its leaves reflect the glory of that golden age when it flourished so abundantly.

Last of the trees to turn is the black cherry. Rather appropriately, it takes on all shades, from yellow to deep red to dark purple—a fitting résumé of events that have transpired, and all the more striking when, in November, the skies are often dark and even the noon-

day shadows are long. At this time, too, the steel-gray bark of the trunks of the beech stands in marked contrast to its light brown leaves.

Although trees play the major rôle in this whole display, shrubs also contribute, especially the sumachs and the blueberries. Most of the sumachs, like the dwarf and the smooth, become bright red or scarlet. At times, though, the staghorn sumach, whose twigs are downy like antlers in spring, takes on all the colors of the rainbow, from violet to red, sometimes in one leaf, and almost in one leaflet. "Infinite shades of color," says the artist; "gradual changes in acidity," says the scientist.

Related to the sumachs is the poison ivy, usually a vine, but shrubby at times. Its leaves are often bright red, in contrast to the ivory white fruits. The latter look like simple symbols of purity, though they are poisonous. Boston ivy shows similar color effects in the leaves, but without a trace of malice.

No other shrubs are so common in eastern North America as the blueberries; some of them are to be found growing in dry soil, while others inhabit swamps and bogs. Almost universally they turn a bright red in the fall; they may augment the colors of the maple, the oaks and the sour gums, or they may stand in sharp contrast to the green of the pitch pine, the southern white cedar and the mountain laurel. Due to the oaks, sumachs and blueberries, much of New Jersey looks toward the end of October as though some giant had passed through the countryside with a single large pot of red paint and had applied it lavishly. Barberry, including the cultivated form, becomes a bright, slightly rusty red. On Cape Cod and in New Jersey the cranberry plants in the bogs turn a dull, reddish purple after the fruits have been picked; at the same time glasswort splashes its vivid red against the brown of the grasses in the salt marshes along our coast.

In dry, rather sandy soil the grasses, especially the beard grasses, may be seen bowing in unison to let the breeze go by. These also become colored in the fall, forming reddish brown carpets on the hillsides. Very slowly do they fade, so that the tints of autumn may still linger at Christmas time; and these grasses often stick up hopefully through the first thin snows. Only long after the winter silence has descended do they fade into a pale yellowish brown.

Not a little is added by the fruits that ripen in the fall. Bittersweet sprawls and twines and shows its orange capsules and scarlet seeds; hollies, growing in swamps as well as in sands, mature their red berry-like fruits; barberry bushes are often laden with red; while hawthorn, after the leaves are gone, shows brilliant red against the blue of the autumn sky.

These are some of the more important contributors to that symphony of color that is played each year on the hillsides of North America. If there is a "hard-frost" or a pronounced "dry-spell," the performance is syncopated, leaving the dark green of the pines and hemlocks and spruces enlivened only by the barks of such trees as the birch, the beech and the red maple.

The brilliant display of autumn is really the result of two sets of factors: one is the wonderful assortment of broadleaved trees in the East, capable of developing these colors; the other is the weather—the clear, bright days and cool, crisp nights that are so characteristic of the fall in our eastern states. "Football weather" is conducive to brilliant foliage, as well as to husky voices on Sunday morning.

On what parts of the earth does this coloration occur? There are only three large areas of temperate broad-leaved

forests on this earth—one in eastern North America, one in eastern Asia and one in Europe, including central Europe and the British Isles. In the southern hemisphere such forests are almost lacking, except for a small region in southern South America, mostly in Chile, and very limited areas in Tasmania and New Zealand.

Eastern North America and eastern Asia are strikingly alike in their plant populations. It may seem rather anomalous that floristically there is a greater similarity between eastern North America and eastern Asia than between our own East and our own West. No places on this earth have a richer assortment of valuable broad-leaved trees than eastern North America and eastern Asia. Our West has matchless forests of conifers, like the pines, Douglas fir, redwood, and hosts of others. In fact, many of the lands that are washed by the waters of the Pacific are rich in conifers. But the West is relatively poor in broad-leaved trees. Climatically, eastern Asia, including much of Japan, is also similar to eastern North America. Consequently, it is logical to find that these two regions both show brilliant colors.

On the other hand, much of northern Europe has cool, damp, cloudy weather in the fall. This is not so true farther south, so that in the Danube valley beautiful foliage does occur. In parts of the Alps, due mostly to shrubs, the colors are also pronounced.

Continental Europe, furthermore, does not have the wealth of broad-leaved trees that occurs in eastern North America, though many of the missing species will grow there if planted. In fact, many of them are found in Europe in fossil form. When the glaciers came down from the north in the last ice age, the plants in North America advanced south before them. Our mountain ranges run north and south, so that this was possible. In Europe, when the ice sheets came down, the flight of the plants was impeded, since the mountain ranges run mostly east and west. Local mountain glaciers advancing probably made the escape still more difficult, and consequently many of the trees perished. The sweet gum, the tulip tree, the hickory and the sassafras, for instance, grew in Europe until the last glaciation. This is known from fossils. Partly because of climate and partly because of the relative paucity of broad-leaved trees, Europe does not have the display that we have here. Eastern Asia largely escaped the last glaciation, while Greenland and Antarctica have not emerged from it to this day.

One topic more might be discussed—namely, the significance of coloration in plants. It is well known and generally accepted that insects are attracted to flowers partly on the basis of their color, though bees, like many men, are red-green color blind. Young leaves unfolding in the spring often show the same tints that are developed in the fall; and it has been suggested that these pigments serve to absorb light and thus raise the leaf temperature. Others claim that the pigments act as a protective screen against certain rays of light that may be deleterious in various ways.

While these last two explanations may possibly be of some significance in autumn coloration, it seems hardly probable that the development of these striking colors in the late fall is very important to the plant. The same trees may get along perfectly well without them, and often do. It appears more likely that the conditions are favorable, the stage is set, and the show goes on, without any deeper significance. Perhaps this is the botanical expression of "art for art's sake." In any event, it is a gracious way of saying good-bye.

THE NEW PUBLIC HEALTH[1]

By Dr. E. V. COWDRY

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FIGURES presented by Dr. Louis I. Dublin, of the Metropolitan Life Insurance Company, indicate that the percentage of the population of 65 years and over exactly doubled from 1860 to 1930—a rise from 2.7 to 5.4 per cent. in a period of 70 years.

According to estimates by Thompson and Whelpton the percentage will again more than double between 1930 and 1970—a rise from 5.4 to 11.8 per cent. within a period of but 40 years.

The predictions of statisticians in this field must be taken seriously. If the actual average length of life turns out to be less than that expected, life insurance companies stand to lose money. Consequently, figures usually err on the safe side. Thus a percentage of 6.3 was anticipated for 1940. When 1940 rolled around the census that year showed an actual percentage of 6.8.

The sudden doubling in the relative number of old people is taking place rapidly. Between 1930 and 1940 the total number increased 2,322,401. The increase in this group was 36.5 per cent., as compared with a 7.2 per cent. increase in the entire population. In some parts of the United States (Dutchess County, N. Y.) the percentage of old people predicted for 1970 has already been surpassed. Just 29 years hence we must therefore expect more than four times as many fathers- and mothers-in-law of 65 years and over to care for as our forefathers had to look after at the time of the Civil War. In round numbers there will be 12 in place of 3 per hundred.

Because female mortality in adult life and especially at older ages is less than that of males, Dublin expects that the majority will be mothers-in-law. A factor in the development of this sexual disproportion, which he does not mention, is that the majority of women do not have to survive the same sudden and awful shock that men are subjected to when retired. Females slip into inactivity more gradually and therefore more safely than males.

In the suburbs of our cities have sprouted like mushrooms thousands upon thousands of tiny houses built to accommodate a man and his wife and perhaps two children. The larger houses of a generation ago are slowly disintegrating. As a result, the old people will be squeezed out of life with their children and grandchildren.

It is important to realize that the second doubling will be effected during the lives of young men and women now in our universities and at the threshold of their careers. What will be their attitude to the problem of caring for this vast throng of aging relatives? Their most impressionable years have been in the era of the New Deal, of unprecedented spending, during which the government has taken over from individuals and from localities responsibility after responsibility. My guess is that they will, with hardly a thought, continue passing the buck to Uncle Sam.

Already an effort to buy a solution by spending has assumed vast proportions. Under the Federal Security Act of 1935 our legislators are simply placing millions of dollars in the hands of the aged where they remain for but a short time. If one half of one per cent. of these

[1] These data, and many others mentioned in this paper, will be found in a book entitled "Problems of Ageing," edited by me and published by the Williams and Wilkins Company of Baltimore.

sums could be devoted to trying to find out how the aged can best be helped, the effectiveness of the 99.5 per cent. would be greatly increased.

As so often happens, a private organization took the lead. In 1939 the Josiah Macy Jr. Foundation, under the presidency of Dr. Ludwig Kast, published the results of a systematic survey of the problem. Encouraged by the foundation, the U. S. Public Health Service established a division of gerontology under the able direction of Dr. E. J. Stieglitz. A new kind of public health is being conceived. It is a union of what is best in medicine and sociology.

Wholesale methods are being supplemented by retail ones. Among the former we at once think of measures which have benefited the whole population and have been largely responsible for the rise in age level: improved water supply, improved foods, better living conditions, vaccination, and so on. It is to be noted that individuals profit almost passively. No particular effort on their part is required. But the retail methods, which are gaining momentum, involve on the contrary the closest cooperation between the patient and physician over long periods of time.

Of first importance is adjustment of the individual, both mental and physical, to the changes that occur in his or her body with aging. These changes we shall refer to later. It is the privilege, not of any governmental agency, but of the medical profession everywhere to aid in the adjustment. What is needed is a return of some physicians to the old-time rôle of guide, philosopher and friend. Unhappily this is made increasingly difficult by the onrush of specialization and the rise of great departmentalized clinics, undeniably good things in themselves. It can not be doubted that what many old people fear, more even than disease and death itself, is the prospect of having nothing to do, of uselessness, of being a handicap on their children. Perhaps the greatest economic and humanitarian contribution of public health in the future is to maintain socially useful activity as long as possible in this very large fraction of the population. In the words of Dr. G. M. Piersol, the goal is "to add more life to the years rather than more years to the life."

While keeping an eye on the liabilities of aging people we must cultivate their assets, which are too frequently ignored. Shakespeare put these words about aging, where they belong, in the mouth of a fool. "And so from hour to hour we ripe and ripe, and then from hour to hour we rot and rot, and thereby hangs a tale." Aging is for Emerson a shedding process: "these temporary stays and shifts for the protection of the young animal are shed as fast as they can be replaced by nobler resources." When we follow up this idea certain facts emerge.

Most aging people past 65 have presumably shed preoccupation in their own careers and responsibility for bringing up their children. They have also shed some of their physical activities and, having retired, possess more time for activities on the higher mental plane. Their outlook on life has changed, but it is unlikely that any one will fully understand this outlook save the aged themselves. If they would speak up it would help a lot. But there is evidence of increasing interest in others and of increasing tolerance of the actions of others. Likewise a breadth of view resultant on experience is noticeable and a new dignity. They become concerned unselfishly in the future in which they will not play a part. They may acquire wisdom. This is, according to Miles, "the characteristic prerogative and contribution of well-preserved age" recognized, we may add, by all the greatest civilizations of Greece, China and other lands and not to be forgotten to-day.

Nature is kind to them. The sensation of pain is often dulled. Both Rolleston and Critchley have called attention to this fact. And for the vast majority death is, in the words of Osler, but "a sleep and a forgetting."

Of secondary importance to adjustment to changing manner of life, though I do not like to admit it, is the shift in emphasis which is taking place from acute to chronic disease. I do not mean that investigation of acute infectious disease should be for a moment relaxed, but that chronic disease is now recognized as the greatest danger. In 1930, 59.8 per cent. of white men aged 60 could look forward to death from cardiovascular renal diseases and 10.7 to death from cancer. For white women the figures were slightly different, 59.5 and 11.9 per cent., respectively. To-day the expectation is more gloomy.

Two points are worthy of emphasis. First, the deaths are not quick, as with infectious diseases; but eventuate slowly, which means a tremendous amount of incapacitation and economic loss to the tune of billions of dollars. Second, the warning signal of pain, often provided by nature for other kinds of injury, is lacking in the early stages.

It is reliably stated that if cancer were painful at the beginning, treatment could be instituted promptly and thousands of lives could be saved. But it may be a mercy that the onset of cardiovascular renal disease is not generally heralded by pain because the period of sickness is longer and the site not localized and susceptible of surgical removal. Moreover, the means of diagnosis of early cardiovascular renal diseases are better known.

Because apathy concerning cancer was so widespread, Congress, on the insistence of Surgeon General Parran, unanimously passed the National Cancer Act. This provides for the National Cancer Institute and for small appropriations to stimulate research by private organizations and individuals. In respect to cardiovascular renal disease, it was the far-sighted Macy Foundation that again made the first detailed examination of research possibilities. But there has been no follow-up. The financial support necessary for research is still lacking.

There are other problems requiring immediate action, of which mention will be made of only one, that of nutrition. Much has been learned about the proper food of individuals in the upswing of life, nothing about that of those in the downswing. This downswing begins before the age of 65 years. It is probably well started at 45 years. In 1940, more than 25 per cent. of the population were 45 years or over. And we complacently remain ignorant of their nutritional requirements in this land of surpluses!

Basic, of course, to public health of the future is detailed information on changes in the body with age. Only in the light of such data can we guide individuals so that, as far as their hereditary endowments permit, they will be enabled to live healthy and useful lives. The task of astronomers, physicists and mathematicians is simplicity itself compared with that before us. While they have to consider a few variables we have them without end. Our concept of the body is that of an aggregate of billions of vital units in unstable equilibrium constantly changing in continual adjustment to environment both external and internal.

No part of the body remains the same throughout life. Many tissues, no longer needed, are discarded. In early life the "before" kidney is succeeded by the "middle" kidney and this in turn by the "after" kidney. The fetal cortex of the adrenal wastes away. Great veins become fibrous cords or entirely disappear. After about a year there remain in the nervous system no short-lived

nerve cells capable of division. Later on, many other sorts of primitive cells drop completely out of the picture.

To provide for wear and tear the larger part of the body is being constantly renewed. With the passage of years, life is maintained by an ever-changing cellular population. The rate of replacement is not uniform but differs for almost every cell type. For some it is rapid; for others very leisurely. No one has yet classified the cell types in order of increasing rate of turn-over. Either the stimulus to cell division is different for each type or the responsiveness of each type is different for essentially similar stimuli. However this may be, replacement of cells in the human epidermis is rhythmic (Cooper and Schiff). The number dividing by night is about twice that of those dividing by day.

Looking further we see an almost endless vista of other and different rhythms, some long, others short; some of great volume, others small; but all related in some way to each other. W. F. Petersen has considered biological rhythms in a very penetrating way. He has called attention to the fact that over a century ago Ernst von Baer compared life to a melody in which rhythm is made up of increases and decreases in functional activity, while harmony and disharmony reflect well-being and disease. To put it differently, not only the radial artery but all tissues pulsate each after its own fashion but not independently, and the whole changes with age in ways that we can imagine but imperfectly.

Coming back to our theme, the parts of the body which are not replaced are likewise of great variety. They include dead and living components. We think at once of dental enamel, of which the replacement is nil. The elastic coats of blood vessels are not effectively replaced, though other elastic fibers form. Nerve cells, cardiac muscle cells and many others, once differentiated, must serve to the end. Among the factors of safety are durability, numerical excess of cells and the duplication of mechanisms. These non-replaceable parts change with time, each at a tempo peculiar to itself and in a host of different ways, most of them unknown.

No two bodies age in the same way, except to some extent those of identical twins. Aging, like dying, is a piecemeal process but slower. One system or organ may outstrip the rest. Different parts of the body have different life spans. Life span is defined as the potential duration of life under the most favorable conditions. The life span of the eye, according to Friedenwald, exceeds that of the body as a whole, while that of the vascular system is obviously relatively short.

Rate of aging is conditioned by factors too numerous to mention, but the chief ones are the inseparables—heredity and environment. The grip of heredity can be felt at almost any age and in various sites. Whether lethal genes exist, as in certain lower forms, remains to be determined. In mice premature and delayed aging of the joints is hereditary, as the Silberbergs have demonstrated. There is some reason to think that the rate of aging of vital rubber in the arteries is partly conditioned by heredity. As our knowledge expands, it becomes evident that the fate of many parts of the body is similarly predestined.

The entire body may be fortunate or unfortunate in the hereditary control of its aging. It is known to all of us that the members of some families male and female, barring accidents, live to a ripe old age without taking any particular care of themselves. But a common factor can be dimly discerned. Some work hard and others little, some are soaked in nicotine most of their lives and others are free from it, yet all, generally speak-

ing, take life complacently and do not habitually worry. They are well adjusted to their physical and social environments. Others would like to be and aren't.

Adjustment to the external environment—involved though it is—is relatively simple compared with adjustment to the internal environment. As we grow old both begin to fail. The response of the endocrine symphony to its conductor, the pituitary, becomes less harmonious with change in the individual pieces. The nervous system frequently drives the rest of the body beyond its dwindling capacity into the grave. This large changing picture of adjustment is a consequence of what is happening in numerous small localities.

All the cells of the body that are alive are aquatic. With the exception of those that live in the streams of blood and lymph or border them, they are all inhabitants of the extra-vascular tissue fluids. Evidence is fast accumulating that these local tissue fluids are not of essentially uniform composition, as W. B. Cannon would have us believe. They are said to be simply ultrafiltrates from the blood. But this is to view them only from one angle and to ignore the fact that living cells reside in them. These cells differ in different localities, and it is not to be expected that they will influence all the tissue fluids in the same way. Moreover, local differences in endothelial permeability are known so that it would be surprising if the ultrafiltrates were of uniform composition. As a matter of fact the chemical composition of subcutaneous tissue fluid, cerebrospinal fluid and aqueous humor of the eye, to mention only three, are distinctly different. It is safe to predict that many other differences will be found, just as we anticipate other rhythms in cell division and other sites of hereditary control of aging.

Of the alterations in these many tissue fluid environments with age, very little is known. If those containing multiplying replacement cells should remain favorable, the presumption is that the descendants of the cells in question would continue in series indefinitely. The reason for this statement is that when some cells of this sort have been removed from the body and have been cultured in appropriate media frequently changed, they have gone on living in series indefinitely. H. G. Wells has truly said parts of Mahomet could be living to-day had they been cultured through the ages in this way. Similarly, when certain malignant cells have been transplanted from animal to animal, the strain of cells has continued alive far beyond the life span of the original host. But owing partly to changes in tissue fluid environments these cells, if confined to the body, die off with age.

Increasing difficulty in the attainment of reasonable stability is the most outstanding feature of aging. A release from controls begins to make its appearance. This is seen to best advantage in the skin. In the epidermis we find areas of hyperplasia and atrophy, of pigmentation and depigmentation, of hypermineralization and hypomineralization. The stage is set by this wavering and instability for the occasional malignant change. It is possible that the same process is at work unnoticed in other deeply situated tissues.

But my time is limited. My immediate purpose has been to give a dynamic sketch of a few of the basic changes in aging of the body. Only the surface of the problem has been skimmed. When we dig more deeply and try to follow the aging of individual cells in their several fluid environments we become bewildered. It clarifies the situation a little to divide the cells into two large classes. The first is made up of those whose individual lives end not by death

but by division into two new cells. These I call intermitotics. They include basal cells of the epidermis, the forefathers of blood cells, spermatogonia of the testicle and many others. They are the replacement cells already referred to. In them, as individuals, it is difficult to find signs of aging though such probably exist.

The second consists of cells which become highly specialized, leave no descendants, age and die. They are by contrast postmitotics. They include nerve cells, cardiac muscle cells and numerous others. It is in them that the signs of aging are most manifest.

Length of cell life, conditioned by factors almost wholly obscure, is within limits characteristic of each type. Preliminary calculations show that individual nerve cells live approximately 2,190 times as long as neutrophile leucocytes. As they age, some kinds of cells become dehydrated, while others do not. Some grow larger, while others decrease in size. Some accumulate pigments altogether absent in others. Many lose specific functions not possessed by others, and so on almost *ad infinitum*. Even death comes in a multitude of different ways depending upon kind of organization, manner of life, vital hazards, etc. And there remains the ever-present task of distinguishing between normal aging and the results of injury and disease at all levels in organization from individual cells, inanimate fibers and tissue fluids up through the organs and systems to the body as a unit.

In brief, however, length of life appears to be limited mainly by the wearing out of the non-replaceable components, nerve cells, muscle cells, elastic fibers, etc.; by hereditary defects or inadequacies in many systems and organs; and by gradual decreases in adaptability to change which may manifest themselves in a wide variety of ways.

Obviously, no single mind can compass even what is now known of the aging of the human body. Fortunately, sociologists, economists and psychologists are meeting the challenge side by side with physicians. The problem presented by this steady increase in the number of aged people is without precedent in history. It is the great problem of the twentieth century.

The tragedy is that old age is *tabu*. A few years ago I was greeted with a smile when I admitted that I was interested in the phenomena of growing old. To-day I am taken more seriously by my younger friends, particularly the pediatricians. But old people often remain their own worst enemies. They are the most grateful of patients. Many hide their heads in the sand, wait like sheep for sickness that could be avoided or made more bearable, give millions of dollars for the medical care of children, whom they find it refreshing to think about, and blind themselves to the welfare of others in their predicament. I am convinced that the problem of aging will never receive the attention it deserves until the best informed among the millions rapidly aging themselves see to it that darkness is dispelled by research. The immediacy of the problem, the second numerical doubling of the fathers- and mothers-in-law, is generating in this country a new public health in which the aged, who have been for centuries the forgotten ones, will share.

SOCIAL NATURE OF SCIENCE

By Dr. L. GUY BROWN

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1. Science After the World War

When the present World War is over there will be many demands for a "tribal" scapegoat in which all blame can be centered. There will be an effort, in true primitive style, to shoulder the blame on many of the obvious elements in the international conflict. One aspect of the tremendous destruction of life and property that is bound to attract attention is the rôle that science has played in war. There is already a strong, rapidly-spreading belief that wars would be ended if science could be curbed.[1] The tragedy of this situation lies in the fact that this belief is based on a misconception concerning the true social nature of science, a misconception created in part by scientists themselves.

[1] Edwin G. Conklin, "Science in this World Crisis," *Vital Speeches*, 5 (1939), p. 334: "There is at the present time a rising tide of denunciation of science for having produced the disorder of society and the savagery of modern wars that are threatening the destruction of the fairest products of civilization. The outcry against science was begun by the theologians of several centuries ago; it was continued by defenders of classical education during the past hundred years; and since the beginning of the century it has been taken up by the self-styled 'humanists'; of late there are signs that all these denunciations of science as the destroyer of peace, progress and ethical values have begun to influence the minds of the masses of mankind. . . . More than forty years ago Woodrow Wilson discoursed eloquently on 'The Bankruptcy of Science,' and within the last decade Christian Gauss has warned us of 'The Threat of Science,' and numerous other advocates of the humanities have proclaimed that civilization must be saved by curbing or removing science and by promoting 'humanism.' . . . One week ago (*New York Times*, February 19, 1939) a speaker warned the National Conference of Christians and Jews that curbs on science are urgently needed and that it may become a Frankenstein monster if unchecked."

Those scientists who steadfastly refuse to recognize science as a social phenomenon but insist that it is an extra-cultural phenomenon, an absolute that has its meaning within itself, invite an attack on science. These scientists ignore the origin of science and the process by which it came into existence. Science is not an outside agent or force but a part of social life which is a unified whole.

As the social nature of science is revealed in this discussion it will be demonstrated that science *per se* will not destroy civilization nor can it save civilization since it does not have its meaning within itself. It can, however, be utilized with equal facility in either direction. Just as science is needed to carry on modern war, it will be essential for establishing peace in the type of world in which we live to-day. This point will be clarified as the social nature of science is revealed.

2. The Origin and Social Nature of Science

"If science is not a social phenomenon it is nothing."[2] That statement by a biological scientist does not have to remain a mere affirmation, its veracity can be established through an analysis of the origin of science and the process through which it developed. It is a matter of historical record that science did not always exist. Its advent into the social world is recent enough to discover how and why it made its appearance. Like all other aspects of social life, *science* and *everything* connected with it are all products of interactive living.

There was a time when there was no social life and no science. These accom-

[2] Paul B. Sears, *The Biologist*, 21: p. 3, 1940.

plishments had to wait until the biological process had produced a species with the capacity to develop human nature and live on a cultural level. Once this was an achievement, the interactive relationship among the members of this species set in motion the social process.[3] Everything found in social life, now or at any other time, was either produced in the social process or was brought into use from the natural environment through this process, that is, through interactive living. Science is not an exception.

When the student of social life discovered that everything in social life was either produced through interactive living or was brought into use from the natural environment in the same way, he began to look for the common denominator in social life. He found this to be the interactive relationship between human nature and social organization. In other words, anything produced in the social process or brought into use from the natural environment is integrated into human nature and social organization. Nothing biological, physical or social has any meaning apart from these two factors, and these two factors have no meaning apart from each other. Thus these two interactive elements make up the common denominator in which science and all other products of interactive living have to be explained.[4] No matter where one makes a cross-section of social life he finds these two factors in interaction with each other.

3. Science As a Social Habit

When the interactive relationship between human nature and social organization was a reality there was need for social habits through which these two phenomena, in their interactive relationship, could become functional. Science is one of these social habits. There are many others, corresponding to the many differentiations in human nature and the social order. Some of these are marriage, education, religion, medicine, law, art, music, agriculture, industrialism, food-habit systems, drinking, magic, war, vice and crime.[5] Each one of these came into existence just as soon as there was human nature and social organization that could be expressed through it. At one time the existing human nature and social organization could be expressed through magic and all other unscientific social habits. In the development of these two fundamental aspects of social life there eventually came a demand for science as a social habit through which these phenomena could be manifested. In other words, there was an accumulation of human nature and social organization that could no longer be expressed through pre-scientific social habits.

Science did not exist in the nature of things waiting to be discovered. It could not become a reality until there was human nature and social organization that could be expressed through it. It has not appeared in those cultures where it

[3] The social process is interactive living on a cultural level. It is the means by which social life is established, maintained and changed. Everything in society was either produced in the social process or was brought into use from the natural environment and given meaning through interactive living. As a part of social life the natural environment is a product of interactive living in the sense that it is in this process that it gets its meaning. The data of the physical and biological sciences are social phenomena in the sense that they have no meaning apart from the social process.

[4] Human nature consists of attitudes, ideas, interests, desires, habits and a philosophy of life. It is the subjective aspect of social organization. Social organization is everything of a structural nature, in relation to which human nature has developed. It includes institutions, organizations and all that was produced in associative living as well as everything in nature that has been given an operational place in society. Natural resources as well as general geographical factors have their functional meaning in human nature and social organization.

[5] All these social habits are abstractions until human nature has been expressed through them.

is not demanded by human nature and social organization. In one culture the natural environment is something to investigate, understand and explain; in another it is something to fear and worship. In the former there is a demand for science, in the latter this social habit is not needed. Magic will do. There are no data in the physical and biological sciences apart from the interactive relationship between human nature and social organization. Apart from this relationship what are physical resources, physical units, electricity, magnetism, the atom, the amoeba, protoplasm, cells, tissues, virus, germs, the solar system, telescopes, heredity, genetics, paleontology, the anatomy of plants, etc.?

Like war and other social habits, science is a human invention, the product of interactive living. It is not what it was when it first appeared since the human nature expressed through it now contains knowledge that did not exist when science first appeared. It will be somewhat altered in the future as the interactive relationship between human nature and social organization changes.

Not only science but everything connected with science is a product of the social process, of interactive living. For each social habit there is a group of specialists, trained to direct and to help to determine the nature of the social habit. Once magicians, priests and philosophers were the chief functionaries in relation to social habits, but when science became a channel through which human nature could be expressed, scientists were produced in the process of interactive living. There is not one method by which magicians, priests and philosophers are produced and another by which scientists are produced. The process is identical in a general way. They are all the results of associative activities. They all became what they are through the development of attitudes, ideas, interests, desires and other human nature attributes. They are social products in the same sense that militarists are social products. Social variants, specialists who keep such social habits as vice and crime operating, were produced through the same general process. It is not possible for any individual to develop his human nature outside the social process of interaction.

"The fundamental proposition is that scientific research is a social process as much as business, political or religious activities, and as such is interwoven with all other social processes, influencing them and being influenced by them. . . . Scientific research, then, is one among many social activities carried on by the people of our culture."[6] It is a human creation, a historical development, and will be whatever man decides it is to be. It will always take the functional form that the interactive relationship between human nature and social order gives it. Since science is a cultural pattern, a part of an interactive whole that includes many other cultural patterns, it is distorted when there is social disorganization in the totality of which it is a part. It is perverted in the same way that family life, religion, education, business or any other factor is perverted. What seems to be the perversion of science is really the perversion of the interactive relationship between human nature and the social order being expressed through science.

Many scientists are ready to regard science as a social habit in its utilitarian form but rebel against having the "pure" science of the laboratory so regarded. However, life is a unified whole, nothing exists in isolation. "Scientific work interlocks from one end of the scale to the other."[7] Science for the purpose of discovery can not be separated from science for utility purposes,

[6] W. C. Mitchell, *Science*, 90: p. 604, 1939.

[7] Julian Huxley, "Science and Social Needs," p. 17.

except in a philosophical sense. In the laboratory the research specialist is expressing his human nature of scientific attitudes, ideas, knowledge, desires, interests, etc., through science; thus it is a channel for the expression of human nature even when its chief function is discovery.

In Nazi Germany where civilian science has become military science both in the laboratory and through an aggressive war, one can see the interlocking relationship throughout scientific work. The relationship between pure science and practical science can be seen in any country in the field of medicine, agriculture and in industry. Furthermore, the same scientist could go into his laboratory one year to discover something to preserve life and the next year enter the same place of research to work on a formula that could be used to destroy life and the third year retreat into the laboratory without caring what the social consequences might be. In all cases he would use the same scientific technique and in all cases science would take the form of the human nature expressed through it. Apart from the interactive relationship between human nature and social organization science is just an abstraction.

So science and scientists are social phenomena, likewise everything connected with the activities of this social habit and its specialized functionaries. The techniques, the terminology, the symbols and all else identified with these social products had their origin in interactive living. It was in the social process that man decided what science should be, what it should study and what it should not consider. Scientific interest and curiosity had their origin in social interaction and programs of research center around social problems that need to be met.

All data, whether they were produced in the social process or were brought into use from the natural environment, are parts of social life. Physical and biological data have no meaning apart from the interactive relationship between human nature and social organization. Nothing is studied until a demand arises in social life. There are no physical or biological data *per se;* they have their meaning only as they appear in terms of the socially acquired knowledge about them.

4. Connotative and Denotative Meanings of Science

Like all other social habits, science has a broad connotative meaning or function and many denotative meanings. The general connotative rôle of science allows for the expression of human nature and social organization. Then there are as many denotative meanings as there are differentiations in human nature and social organization that can be manifested through science. The scientist can express his human nature through it but so can a dictator, a criminal or any one interested in destroying life and property.

The denotative meanings are almost as numerous as the great variety of human activities. Science is used by human beings in a social setting to secure control over everything produced in the social process and everything brought into use from the natural environment. It is used by human nature and social organization to get control over three important processes: the biological, the geographical and the social. Man uses it to understand his own place in the universe, to satisfy his socially produced desires for manipulation, to relieve his curiosity and for the pleasure that he gets from using his socially defined intellectual processes.

There seems to be almost no limit to the great diversity of uses for this social habit. In some situations one observes human nature searching for knowledge,

superior knowledge, tested and retested and systematized. In another relationship, questions are being answered about the origin and nature of things with an effort to explain reality and get rid of delusions, superstitions and to eliminate error. It may be a way of thinking, of testing a hypothesis, of discovering laws and unifying principles or for making classifications, predictions and interpretations. Human nature may be expressed through science to achieve safety, to lead to inventions; and quite as important, human nature may be expressed through science to preserve or destroy life.

5. Science is Neither Normal nor Abnormal

Science *per se* is neither normal nor abnormal. As a social habit, the product of interactive living, science is amenable to the expression of any type of human nature and social organization. It is this unlimited range of flexibility that makes science the great social habit that it is. Its greatness is revealed in the expression of destructive human nature quite as much as it is when constructive attributes are manifested through it. Later, it will be pointed out that much of the destructive human nature and social organization expressed through science was produced in the first place through other social habits that have social approval.

Science has no cultural favorites and no preference in types of human nature. The functional nature of science makes it limiting and permissive but not mandatory in nature. The control of science does not necessitate a single change in the nature of science *per se,* but it does depend on the modification of the interactive relationship between human nature and social organization. When science made its appearance as a social habit, war was already a cultural pattern; political and religious conflicts were well established; the idea of exploitation was not new; there were already ancient prejudices, hatreds and many misconceptions about life. Few people saw life as a cooperative quest, or rights as human rights. Rights were the prerogatives of certain groups; they were not human rights. This was the nature of the social life that was ready to be expressed through science or any other social habit when science appeared in society.

One need not be surprised to see science taking the form that a totalitarian state demands. Like any other social habit, it has to take the form that the interactive relationship between human nature and social organization gives it. Science and scientific research emerge out of the growing needs of society, whether that society is a democracy, a totalitarian state or any other way of life. In each one of these forms of government scientists go into their laboratories to meet the needs of society. Even in peace times some governments spend almost as much for poison gas research as they do for medical research.

Science can have no objective functional existence apart from nationalism, apart from the historical religious and nationalistic hatreds of Europe and Asia, apart from such misconceptions as a pure, superior race that has a right to subjugate other groups. Science has no objective existence apart from the imperialistic ambitions of the past and it can have no existence to-day apart from the aggressive attitudes and imperialistic plans in the Orient and the Occident. Science, as a social habit, can be used for the aerial destruction of life and property and sabotage in every conceivable form. War, viewed from one angle, is the utilization of science to express the interrelationship that exists between human nature and the social order. War is the utilization of science to express human nature in its patho-

logical aspects and to make functional such cultural patterns as nationalism, economic exploitation, political subjugation, imperialistic ambitions and all other forms of economic, political and cultural pathology. Science has no chance to escape any form of social disorganization. But remember science did not produce all the human nature that is expressed through it. Any type of pathological human nature now expressed through science existed before science was a social habit. The control of science will be achieved only when there is social control of the interactive relationship between human nature and the social order.

6. Science and Other Social Habits

The necessity for recognizing science as a social phenomenon is seen when there is a realization that much of the destructive human nature and social organization expressed through science was developed through other social habits. Prejudice, hatred, intolerance, delusions of persecution and accusatory attitudes demanding a vindictive outlet, revealed through science and war, were developed in religion, in family life and in education. For instance, neither science, war nor the Nazi way of life placed the Jews in a position to be persecuted in Germany. Nor was their economic supremacy the chief cause of their persecution. Long before science was a social habit, the church, the home and the school placed the Jews in this position, not only these fundamental institutions among Gentiles but among Jews as well. This is not a criticism of these fundamental institutions *per se*. They take any form that the existing human nature and social organization give them.

The point here is that science is often blamed for human nature produced in other habits. The theologians, humanists and others often attack science for human nature produced in their own fields, in non-scientific social habits. Science as a social habit has no functional existence apart from non-scientific social habits. It is well for the scientist to realize this if he does not want science blamed for behavior that came to actualization in other social habits, but this means recognizing the social nature of science.

In a life that is a unified whole, all of which was either produced or given meaning through interactive living, science can be mobilized for a single purpose along with other social habits. There is a total war at the present time with the entire interactive relationship between human nature and social organization pointed in this direction. Science, pure and utilitarian, is now a much used social habit for the prosecution of war. Education, religion and other social habits are mobilized in the same fashion. All these can be used when social life is organized for peace.

7. The Future Rôle of Science

There is one way to predict the future of science, either as a pure science or as a utilitarian science. This can be done only through a knowledge of the interactive relationship between human nature and social organization. It was evident to any student of social life that science would be mobilized for the destruction of life and property in Nazi Germany and Japan. The human nature of a whole generation was marked by hatred, ideas of persecution and grandeur, and accusatory attitudes demanding a vindictive outlet. The interacting social organization was militaristic in nature. How could any one do other than predict aggressive war in that situation, with science and all else mobilized for war? War is inevitable when the proper interactive elements are present and peace will be just as certain when the interactive relationship between human nature and social or-

ganization tends strongly in that direction. Social prediction is possible, just as possible as prediction in any other field.

Prediction concerning the future functional nature of science depends on knowledge concerning the character of the interactive relationship between human nature and social organization. More than this, the control of science depends on the control of this interactive relationship that gives science its meaning. Despite these facts there are still some natural scientists who believe that the interactive relationships between human nature and social organization are not even data to study, understand and explain. A biologist recently remarked that there is not a field of sociology.[8] This statement shows a naive conception concerning fields of study—a belief that academic disciplines exist in the nature of things waiting to be discovered. Actually they exist only in the minds of men. There is a field of study when individuals mark out a certain area of life and give it a name. The boundary lines between all present fields were drawn elsewhere at the outset. Doubtless new boundaries will be fashioned and some disciplines may disappear and others may be established in the thinking of men.

The same biologist who does not believe that there is a field of sociology thinks there is a discipline of anthropology, not realizing that the anthropologist studies the same general types of phenomena studied by the sociologists. The anthropologist studies the interactive relationship between the human nature and social organization of a preliterate group while the sociologist studies this interactive relationship in our own society. Primitive man is produced in the biological process in the same way as man elsewhere is produced and belongs to the same species as all other human beings. His social organization and human nature are achieved through interactive living in precisely the same way that these phenomena are produced anywhere.

The natural scientist encourages the study of social life among primitive groups but may not want his own social milieu investigated. Yet it is here that war, vice, crime, exploitation and other forms of social disorganization are integrated on a large scale. It is here that science is perverted and becomes the social habit through which personal and social disorganization are expressed. It seems incredible that a scientist should object to the study of the phenomena that determine the operational nature of science. If the phenomena studied by the social scientist disappeared there would be no science. If these are not understood and controlled science may be used to destroy civilization—all of social life.

A scientist lives in a social life that is a unified whole and needs, therefore, a connotative mind as well as a denotative mind. He needs the latter for research in his own field and the former so that he may recognize the broad perspective in which his own field exists and see the essential relationships between all fields of study. A scientific mind regards every aspect of life as a phenomenon to be studied, understood and explained. A scientific mind does not want any misconceptions existing regarding any aspect of life.

Some physical and biological scientists do not want to recognize the fact that

[8] Sociology describes the social process, revealing its origin and nature, and shows how each aspect of social life was either produced in the social process or was brought into use from the natural environment and integrated into human nature and social organization. In addition to this general function sociology analyzes and explains the cultural aspects of the interactive relationship between human nature and social organization as distinguished from the economic and political aspects. There is a field of sociology only because a group of specialists marked out an area of life that was not being studied by any other group.

science is a social phenomenon. They want to raise science above the process in which it was produced and above the situation that gives science its meaning—an insuperable task, of course. Nothing in life can transcend the interactive relationship between human nature and social organization and nothing can be placed below it. The natural scientist often ignores his relationship to the social scientist, yet the social scientist studies the phenomena that give science its operational meaning. Science could not even come into existence until the phenomena studied by the social scientist had developed far enough to demand science as a social habit for its expression. Some scientists believe that the interactive relationships between human nature and social organization are not even data to be studied. They claim that it is not a concern of theirs if science is used for the destruction of life and property. Their only function is discovery, but this is not possible except where the interactive relationship between human nature and social organization permits this activity. After the present war, there may be a drive to stop scientific discovery unless its social nature is understood.

If the scientist is interested in freedom of inquiry, concerned with freedom of experimental verification, anxious about freedom for full publication, then he can not afford to ignore the interactive relationship between human nature and the social order, since it is here that the freedom of science will be established. The spirit of science, functionally speaking, is what it can become in the society where it exists. It is evident that the plan of life in some parts of the world involves the destruction of life and property, and there the spirit of science is in line with existing human nature. One of the chief interests of any scientist at the present time should be a concern over having the interactive relationship between human nature and social organization studied and understood. This is necessary for social control which will determine the nature of science.

Instead of saying that the interactive relationship between human nature and social organization is not a datum to study the scientist should demand that it be studied since it is in the control of this relationship that the nature of science will be determined.

The enemies of science call it a Frankenstein monster, but the monster is the interactive relationship between human nature and social organization. In its general form this Frankenstein monster existed before there was a well-developed social habit of science.

8. The Sociology of Science

It is possible to write the sociology of science just as it is feasible to present the sociology of marriage, crime or any other social habit through which human nature and social organization are made functional. Science is a social phenomenon in a general class with all other factors produced in the social process and the human nature of a scientist is the same general type of phenomenon as the human nature of a dictator. Both achieve their life organizations in the same way and both can express them through science. There is a social psychology of scientific thinking just as there is a social psychology of criminalistic or religious thinking. There is a social-psychological explanation for the scientist who does not see his relationship and that of science to all life, just as there is an explanation for the social variant who does not see his essential relationship to life.

It will be possible to save science after this World War only if its true social nature is recognized by every one concerned.

AMERICA'S AFRICAN ODYSSEY

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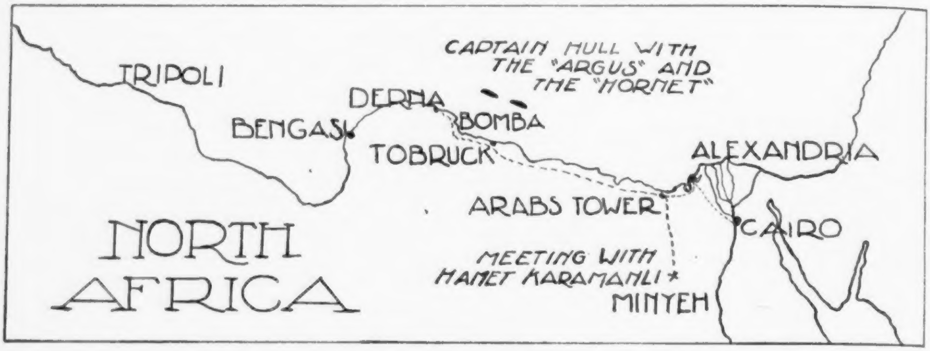
THE war has focused its great searchlight upon the North African shores of the Mediterranean. Libya, Siddi Barrani, Bardia, Tobruk, Derna, are counters quite passable in any conversation of to-day. We watch with intense interest the march and counter-march of the British, Italian and German armies along this narrow strip of coastline. So did Americans of more than a century ago concentrate their attention on this same North African shore; for along it was enacted a thrilling incident in American history. It was along this coastline that General William Eaton led a motley army of Americans, Italians, Greeks and Arabs across this same desert route with the object of rescuing some three hundred American officers and sailors held captive by Yusuf Bashaw, the Dey of Tripoli.

General William Eaton, the hero of this forgotten episode in our history, had served in the American army with distinction, but in 1801 retired to take an appointment as United States consul at Tunis. Then Tunis was one of the small states strung along the African coast of the Mediterranean, which existed solely by pirating the vessels of the Christian nations and by selling their crews into slavery throughout the Mohammedan world. These states were collectively known as the Barbary states, and it is to our everlasting honor that we, the youngest and almost the weakest of the nations which traded in the Mediterranean, were the first to attempt to clean out this nest of pirates and slavers. Out of our wars with the Barbary states was born our navy. Nearly every one of those naval commanders whose exploits fill the pages of our early history received his baptism of war in raids against Tripoli, Tunis and Algiers. It was in these waters that Stephen Decatur, John Rodgers, David Porter, Oliver Perry and a host of others won their first fame.

In 1801, the Bashaw of Tripoli, dissatisfied with the amount of tribute we were willing to pay him to refrain from molesting our ships, declared war upon us. President Jefferson dispatched a strong squadron to the Mediterranean to blockade the shores of Tripoli, but, despite these measures, the Bashaw's galleys continued to put to sea and to capture American vessels and enslave their crews. What was of much greater misfortune was that one of our largest naval vessels, the frigate, *Philadelphia*, in pursuing a Tripolitan galley too near the coast, ran ashore and, before she could be floated, was captured with her entire complement of officers and crew, numbering some three hundred men. These men were immediately thrown into the most horrible slavery, and it now became imperative for the American squadron to capture the city of Tripoli and thus release their comrades. This, then, was the setting which provided General Eaton with his opportunity to win undying fame in our history and the gratitude of his countrymen. In the end he won neither. Nevertheless, he conceived and carried through a project which played a determining part in bringing the Bashaw of Tripoli to make peace with the United States and to release the three hundred American sailors he held as captives in his dungeons.

Eaton landed in Cairo, the capital of the then Turkish province of Egypt, in December, 1804. His purpose was to put



MAP SHOWING GENERAL EATON'S ROUTE

into execution a project he had been long nursing in his mind. This project had for its object nothing less than to raise a small force of Arabs and whatever Christians he could induce to follow him and with this force to march across the Libyan desert lying between Egypt and Tripoli and to attack and capture Tripoli from the rear. President Jefferson had granted him some twenty thousand dollars to carry out this project and Eaton had received the rather vague promise that he would be supported as he advanced along the coast by one or two small vessels to be detached from the American squadron. His instructions were so vague that he likened himself to the Spartan warrior who, when asked by the King of Persia whether he came on public or private business, replied, "If successful, for the public; if unsuccessful, for myself." Eaton had induced to follow him in this adventure three officers from the American squadron and six marines. To this small force he subsequently was able to add a young Englishman, an Italian physician and a retired Tyrolese colonel of artillery. Around this nucleus he hoped to gather a body of Arabs which would be augmented as he successfully advanced along the coast towards Tripoli.

Eaton's scheme was not altogether a mad one, for he placed most of his hopes in the fact that the Bashaw of Tripoli was a much-hated usurper who had killed one brother and driven another into exile in order to seize the throne. Eaton had come to Egypt with the specific purpose of seeking out the rightful ruler of Tripoli, Hamet Karamanli, the exiled brother of the usurper. Eaton believed that, if he could find this Hamet and induce him to march across the desert, many Arab chiefs would flock to Hamet's standard, and the success of the venture would be assured. The first problem, therefore, was to find Hamet Karamanli.

When Eaton landed in Cairo, he found that the country was disturbed by one of the periodic revolts of the slaves or Malemukes against their Turkish masters. What was his dismay, however, to find that Hamet, having no other means of subsistence, had thrown in his lot with the Malemukes and was now attached to one of their chiefs, about one hundred and ninety miles inland from Cairo. Nothing daunted, Eaton, who was a master of flattery, induced the Turkish governor of Egypt to issue a firman granting Hamet a safe conduct out of Egypt. The governor probably issued this order with his tongue in his cheek, for he surmised that as soon as the Malemukes found out that Hamet was going to desert their cause, they would quickly kill him. Eaton found that there was no other way to get Hamet than to go into the desert interior and literally kid-

nap him away from the Malemukes. This was a perilous undertaking, as the country was filled with roving bands of robbers who would not hesitate an instant to rob and kill a party of foreigners. Nevertheless, Eaton, accompanied by some of his American companions, started into the desert in search of Hamet. After having proceeded for some seventy miles they were detained by a body of Turkish troops, but Eaton by flattery and bribery won over the Turkish commander and induced him to send an Arab chief to the Malemuke camp for Hamet. In the meantime Eaton and his companions, although hospitably entertained by the Turkish commander, realized that they were under arrest and that if the messenger sent to get Hamet did not return with him, they would very likely be hanged as English spies. The French consul at Alexandria had been busy spreading rumors that they were English officers sent to spy out the country and that the story about Hamet was merely a fiction designed to cover their real purpose. Fortunately, after several days, the messenger returned with Hamet, thus convincing the Turkish officer of the truth of their story. Eaton had little difficulty in inducing Hamet to fall in with his plans, and a rendezvous was appointed at the coast where the expedition was to gather.

After many delays, due chiefly to the fact that Eaton had entrusted most of his funds to one of the party for the purpose of purchasing the necessary supplies and that this individual had embezzled or misapplied most of the funds, the small army, on March 3, 1805, started its long march along the coast. Its immediate object was to capture the city of Derna, some six hundred miles west from Alexandria. After this Bengasi was to be taken, thus opening the way to an attack on the city of Tripoli. The company, as it finally was constituted, consisted of General Eaton in command, assisted by three American officers and six American marines, a company of twenty-five cannoniers, mostly Italians, and a company of twenty-eight Greeks. The rest of the force was made up of several Arab chiefs and about a hundred of their followers. Their armaments consisted of one field piece, supplemented by fifty or so muskets. The loyalty of the Arab chiefs was thoroughly undependable, and during the march across the desert, they were continually deserting and then rejoining the little army. A hundred and seven camels and a few donkeys with their drivers were hired to carry the baggage and supplies.

Before starting on the march, Eaton drew up a regular treaty between Hamet Karamanli, as rightful ruler of Tripoli, and the United States. In this treaty he promised the aid of the United States in replacing Hamet upon the throne, while Hamet promised to release all American captives held by his brother and to carry on peaceful relations with the United States thereafter. A curious feature of this treaty was that Eaton required Hamet to assign to the United States the annual tribute paid to Tripoli by Sweden, Holland and Denmark. This was for the purpose of recompensing the United States for the expense incurred in restoring Hamet to the throne.

In the first few days, the impromptu army made good progress, averaging about twenty-five miles a day. But there soon began a continuous series of difficulties which would have discouraged almost any one else. Eaton, however, remained calm throughout the journey across the desert and never once seems to have entertained the thought of giving up the expedition. On March 10, the camel drivers and footmen revolted, demanding more pay before they would move on another mile. Eaton partially met their monetary demands, but succeeded more by fair promises in inducing

them to go on. Such incidents as this became a matter of regular occurrence, and, more than once, the camel drivers departed with their camels, leaving Eaton and his companions stranded in the middle of the desert. However, by extravagant promises, he would get them to return and the march would be resumed.

Even rumors of good fortune endangered the lives of the small party of Christians. On March 13th, a messenger arrived from Derna with the report that the people of the city had revolted and caused the governor to take refuge in his castle. Afterwards, this rumor proved to be false, but, such was the excitement of the Arabs over this news that they immediately began to celebrate by riding their horses wildly around and shooting their guns into the air. This in turn almost brought disaster on the company of Greeks and Italians.

As Eaton notes in his diary, "In consequence of the good news, feats of horsemanship and a feu de joie were exhibited in front of the Bashaw (Hamet) by his people. Our foot Arabs, who were in the rear with the baggage, apprehending we were attacked by the wild Arabs of the desert, attempted to disarm and put to death the Christians who escorted the caravan. They were prevented by an Arab with some consideration among them."

By March 18th, Eaton's supply of cash had so dwindled that he was forced to borrow money from his officers and men in order to pay the camel drivers to carry them on further. Furthermore, due to the thievery of the Arabs, their supply of food began to disappear at an alarming rate, so that they were soon reduced to hard bread and rice. This brought on a real crisis, for on April 8th, the Arabs mutinied and refused to go further unless new supplies were received from Bomba from the American war vessel that had been detailed to meet Eaton there. The Arabs drew off in a body and began to prepare to charge the supply tent. The Christians lined up before it and were able to resist the first onslaught of the Arabs, who now withdrew a short distance.

Eaton has left a vivid picture of the whole incident in his diary. He says:

> Discovering an intention among the Arabs to seize our provisions, I beat to arms. My Christians formed a line in front of the magazine tent. Each party held an opposite position for the space of an hour. The Bashaw dismounted and pitched his tent. Supposing the tumult tranquillized I ordered the troops to pass the manual exercise, according to our daily practice. In an instant, the Arabs took alarm; remounted and exclaimed, "The Christians are preparing to fire on us." The Bashaw mounted and put himself at their head, apparently impressed by the same apprehension. A body of about two hundred advanced full charge upon our people, who stood their ground motionless. The enemy withdrew to a small distance, singled out the officers, and with deliberate aim cried "fire!" Some of the Bashaw's officers exclaimed, "for God's sake do not fire." Mr. O'Bannon, Mr. Peck and young Farquhar, stood firmly by me. Salem Aga, captain of cannoniers, his lieutenants, and also the Greek officers, remained steadfast and at their posts. The others were agitated and in fact abandoned us. I advanced towards the Bashaw and cautioned him against giving countenance to a desperate act. At once a column of muskets were aimed at my breast. The Bashaw was distracted. A universal clamor drowned my voice. I waved my hand as a signal for attention. At this critical moment some of the Bashaw's officers and sundry Arab chiefs rode between us with drawn sabres and repelled the mutineers. The fracas nearly resumed its rage when I took the Bashaw by the arm; led him from the crowd and asked him if he knew his own interests and his friends. He relented and called me his friend and protector; said he was too soon heated and followed me into my tent, giving orders to his Arabs to disperse.

On April 5th, the half starved company reached the Gulf of Bomba, the site of the present Italian base of Tobruk. Eaton was greatly distressed not to find there Captain Hull and the *Argus*, which was to bring him supplies and money. This did not keep him from remarking in his diary on the fine situation of

Tobruk, and he predicts that some day it would make a fine harbor and roadstead. That night he lighted fires on the surrounding mountain peaks, with the result that the next morning Captain Hull appeared in the Bay with the *Argus* and the *Hornet*. Supplies were soon conveyed ashore, and Eaton and his motley following now resumed the march towards the city of Derna. They found the city well defended by the Governor and also learned that the usurper, Yusuf Bashaw, had sent reinforcements which were encamped on the western side of the town. Fortunately for Eaton the day after their arrival outside of Derna, three vessels from the American squadron, the *Argus*, *Nautilus* and *Hornet*, arrived off the town. Eaton now sent a demand to the Governor that he surrender, but the Governor's only reply was the laconic message, "My head or yours." On the 26th, the attack was opened. Eaton and his Christians posted themselves on a prominent height overlooking the town, but they were soon opposed by a considerable body of Arabs. What was worse was that their one gun temporarily was put out of commission by having the rammer shot away. Eaton also received a nasty wound in the wrist.

In this crisis Eaton reports that "I perceived that a charge would be our *dernier* and only resort. We rushed forward to a host of savages more than ten to our one. They fled. . . ." Within three hours the city was in the hands of Eaton and his forces, but its capture had cost the lives of two of his marines. Among the Greek foot soldiers fourteen were killed and wounded, of whom he remarks "in this engagement they supported their ancient character." It was in the hour of victory that Eaton almost disgraced himself in the eyes of both his Arab supporters and his Arab foes. The Governor, seeing the city lost, had taken refuge in the harem of one of his sheiks. This Sheik favored Hamet but, the Governor having taken refuge in his house, it became his sacred duty to protect him and to aid him to escape. Eaton committed the error of urging that the house be stormed and the Governor forcibly arrested, not realizing the sacredness of the harem as a place of refuge among the Mohammedans. All demurred, and during that same night the Governor, aided by his host, succeeded in escaping. The next day this same Sheik came out openly in favor of Hamet Bashaw. In offering his aid he took the opportunity to reproach Hamet for even listening to Eaton's proposal to invade the sanctity of the harem. As recorded by Eaton, the Sheik made a very noble speech. He said:

> I have this day given you, I trust, an unequivocal demonstration of my personal attachment and fidelity. I ought to say to you that you have not merited it. You would have yielded to the instances of the Christian general in violating the hospitality of my house and or degrading my honor and my name. You should recollect that not quite two years ago you were saved in this same asylum, and secured your escape by the same hospitality from the vengeance of the very same Bey. Had fortunes of this day gone against you I should have suppressed these sentiments of reproach. . . .

Derna having been captured, Eaton now wanted to push on to Bengasi and Tripoli and with the aid of the American squadron reduce the capital of Yusuf Bashaw, thus effecting the rescue of the three hundred American sailors held in his prisons. But Commodore Barron, in command of the squadron, disagreed with this plan. He felt that his instructions left him no other alternative than to make peace with Yusuf Bashaw as soon as the latter showed signs of wanting to come to terms. The fall of Derna had brought Yusuf to this frame of mind. In vain Eaton pleaded that the United States was committed to aid Hamet in regaining his throne and that if we now deserted him, his brother would take a terrible vengeance upon him and upon the people of Derna for having allowed their

city to be captured. Barron, however, was more concerned with the immediate release of the crew of the *Philadelphia*, and he entertained some fear that if Eaton were permitted to march against Tripoli, the lives of these captives might be endangered. On June 11th, the *Constellation* arrived from Tripoli with the news that peace had been concluded and ordered Eaton to evacuate Derna immediately. Eaton realized that if this news were to become known among the people of Derna, they, in their rage and despair at being deserted, would immediately turn upon him and his Greek and Italian followers and massacre them. He therefore, spread the report that the *Constellation* brought reinforcements and supplies and that the march to Tripoli was to be resumed. That night he smuggled his Christian followers aboard the *Constellation* and then he prepared to leave the city to the vengeance of the followers of Yusuf Bashaw. He says of this moment, "When all were securely off, I stepped into a small boat which I had retained for this purpose, and had just time to save my distance when the shore, our camp and the battery were crowded with the distracted soldiery and populace." Bitter indeed was his thought as he watched the city fade astern. He believed that he had been led to trick Hamet and his followers into furthering the interests of the United States and that once those interests had been secured, Hamet and the city of Derna had been betrayed to the cruelty of Yusuf Bashaw.

General Eaton returned shortly after these events to the United States, where he was received as a conquering hero. The populace believed that his march across the desert had been instrumental in securing the release of the three hundred sailors of the *Philadelphia*. The Administration and Congress thought differently. A motion to grant him a medal was defeated by Congress, and his financial accounts became a subject for Congressional inquiry. He had spent ten thousand dollars more than Jefferson had allotted him, about thirty thousand dollars in all. His accounts were none too carefully kept, and this became of more concern to Congress than the very evident fact that he had accomplished single-handed a most remarkable feat which had greatly aided the United States to bring to an end the war with the Bashaw of Tripoli and to secure the release of the *Philadelphia* captives. Thereafter American commerce in the Mediterranean was free from molestation. Massachusetts, the state which had suffered most from the depredations of the Barbary corsairs, was more liberal in her treatment of this unique hero. He was given a farm of ten thousand acres by the State Legislature. He died there in 1811 at the age of forty-seven, his health broken by his arduous adventures and his spirit broken by the ingratitude of Congress.

BOOKS ON SCIENCE FOR LAYMEN

THE LIFE OF WILLIAM HENRY WELCH[1]

BECAUSE of Dr. Welch's lack of interest in a biography of himself we were in doubt as to which of those we had considered for this task might seem best to him, until by chance, in discussing a biographical sketch of his father, I mentioned this list and at once he chose Flexner, so that next day our advisory board formally asked Dr. Flexner to undertake it. This was shortly before Dr. Welch's death, and whatever the affection and enthusiasm with which it was undertaken it is obvious that this was an enormous task, for there were so many letters and documents to be analyzed, so many acquaintances and so many huge institutions to be consulted, that to put together a continuous story of his life and of all his accomplishments was obviously the work of years.

But we feel that it could not have been more successful. With his long close association with Dr. Welch and with interests quite corresponding with his own, not only in pathology but in the organization of great institutions, no one could have had a better background for the work.

The description of the family, of his boyhood life and education and his early years in New York with his growing interest in pathology and in the teaching of small groups of students is vividly told, and the conflict in his own mind, but especially among his friends, as to his acceptance of the place at the Johns Hopkins University is finally cleared.

Throughout the remainder of the book there is presented an admirable revelation of his personality, which was not merely impressive because of his great ability and his extreme erudition, but lovable because of his human sympathies. As the teacher of pathology and bacteriology, with his never to be forgotten lectures and his personal contacts with his pupils, he will ever be remembered. But with the public and all those in authority it was the same, and his wisdom in any project was awaited with complete confidence.

His numerous visits to European countries, where he spent much time in the laboratories of the most famous workers, impressed them with the same high opinion of his extraordinary intelligence and ability, and they too were, for always, attached to him as a man.

Consequently throughout his life, after he became established in the developing of Johns Hopkins University, he was called upon for such active participation in the proceedings of many societies, and in the organization of so many scientific undertakings that his life was laborious.

As an active investigator in his own subject he did contribute a number of scientific results, among which perhaps the best was the discovery of the gas bacillus. But his papers on more general subjects, such as fever, infection of wounds, adaptation in pathological processes, etc., are very impressive.

In this biography it is made especially evident that his genius was endowed with the ability to realize and foresee the importance of certain fields in medicine in relation to the welfare of the nation or of the world, and to outline the organization of the institutes for this purpose, and even to select those who should form their staff of workers, and especially one who should be director. So successful was he in presenting such a plan, that with the aid of his fascinating personality he acquired such enormous gifts of money that one after another of these plans was thoroughly established.

[1] *William Henry Welch and the Heroic Age of American Medicine.* Simon and James Thomas Flexner. Illustrated. x + 539 pp. $3.75. 1941. Viking Press.

The description of his numerous journeys, even to China and other countries, bears with it the same atmosphere of eager reception of him by people anywhere in the world, for his character was famous.

On the whole it seems that this presents an extremely satisfactory description of Dr. Welch—not only in the details of his whole life, but in the clear picture of himself and of his extraordinary accomplishments.

W. G. McCallum

MATHEMATICS MADE INTERESTING[1]

In the past decade a number of mathematical books have broken with the drier-than-dust tradition in an attempt to show students and laymen that mathematics did not end with Euclid, or even with Descartes and Newton. Professor Merriman's book is of this kind and, in the reviewer's opinion, should accomplish the end for which it was designed.

Although the topics presented are those of the usual college course for non-specialists, the treatment is not stereotyped. Frequent mention of post-Newtonian contributions to quite elementary mathematics enlivens the presentation and should stimulate further interest. The outlook is broadly historical, setting mathematics in its just perspective in the general development of culture. The student who goes through this course may not acquire the dexterity necessary to reduce an algebraic fraction as complicated as a Chinese pagoda to relative flatness, and he may finish without the technique demanded for eviscerating a moderately fantastic definite integral. But he will have learned that mathematics did not petrify 2,000 or 300 years ago.

To give some idea of the contents, the following are a few of the thirteen chapter headings: "The Fountainhead"—number; "Algebraic Counterpoint"—algebra, but not as in the texts for the College Entrance Board examinations, thank God (and the author); "Euclid Alone"—incidentally querying Edna St. Vincent Millay's "Euclid alone has looked on Beauty bare"; "Declaration of Independence"—functionality; "Eventually, and Forever After"—limits and continuity; "Period Piece"—goniometry; and last, "Peak in Darien," which conducts the reader to a high place where he may be as lonely as he likes, and from which he can look out over the expanse of mathematics.

An appendix of 67 pages contains numerous bibliographical notes, problems of an interesting kind and amplifications of the text. Any student of college mathematics should find much to interest him in this unusual text, even if used only for collateral reading.

E. T. Bell

[1] *To Discover Mathematics.* Gaylord M. Merriman. xi + 435 pp. Illustrated. $3.00. January, 1942. John Wiley and Sons, Inc.

ORNITHOLOGISTS OF THE UNITED STATES ARMY MEDICAL CORPS[1]

A book bearing the title "Ornithologists of the United States Army Medical Corps" may well strike one as something strange. Coming off the press just now, in the midst of a great war, it may seem like a breath from a past age—when even warfare was less intensive and army doctors had time and opportunity to study and collect birds while engaged in their professional duties. However, when it is recalled that the army was the great exploring, as well as the military, branch of the government during the opening up of what are now our western states, it is less surprising to see what great contributions to all fields of descriptive science were made by its more gifted personnel. Thirty-six army medical men are given due biographical treatment and grateful evaluation for their ornithological work in the present vol-

[1] *Ornithologists of the United States Army Corps.* Edgar Erskine Hume. Illustrated. xxv + 583 pp. $5.00. 1941. Johns Hopkins University Press.

ume. Only regular army men who were ornithologists are discussed; no ornithologists, who, by virtue of a war, were temporarily in army medical units, are included. While a number of the scientifically more outstanding of these men have been made the subjects of biographical memoirs before, their biographers lacked the military data as to their careers and were forced to treat them as they would have treated civilian naturalists. It was understood, of course, that it was the fact that they were in the army that gave them their opportunities for travel and collecting in out-of-the-way places, but each man was treated as an individual case, and the role of the army as an active agent in natural history exploration was never sufficiently stressed.

Inasmuch as these army trips were official governmental assignments, the materials collected naturally gravitated to the United States National Museum or, before its inception, to its parent institution, the Smithsonian Institution. Here the accumulations from these field activities were carefully studied and the results given adequate publication either in Smithsonian publications or in those of the War Department. In this way, the work of the army medical naturalists was not only utilized to the full but was given world-wide continuing usefulness in generously distributed publications. It is, therefore, a happy coincidence that the foreword to this book is written by Dr. Alexander Wetmore, assistant secretary of the Smithsonian Institution and director of the National Museum.

Students of American birds, long familiar with the names of such men as Bendire, Cooper, Coues, Heermann, Mearns, Shufeldt and Xantus, will find much of interest in this book, much that is new to them, and will learn of the lives and work of other ornithologists less well known to them. Army men may learn with surprise and with no small satisfaction of the contributions to even a limited, specialized branch of science, made by their medical colleagues. The book is an important contribution to the history of natural science in America.

HERBERT FRIEDMANN

SCIENCE FOR CHILDREN[1]

BERTHA STEVENS is a wise teacher. This book follows her "Child and Universe" and "Thoreau, Reporter of the Universe" and, like them, is addressed to parents and teachers. It is a beautiful model for the instruction of young children and for answering their questions as they explore their world. It is exquisite in its poetic and imaginative values; it is realistic in beginning, as children do, with concrete objects and in stimulating and answering the bouquet of questions that burst into bloom whenever a new experience enters the mind of a child.

The subjects of the ten chapters are mundane enough: a star, a magnet, a salt crystal, a dew-drop, a lima bean, a petunia, a tree, a snail shell, a goldfish and a human hand. Each is illustrated with beautiful photographs and with clear, clever, line drawings. Each also has a list of references for further reading—in case the parent or the teacher himself becomes engrossed in the study. Teachers of science for young children should by all means study Miss Stevens's appreciation of the use of poetry, art, embroidered imagery and the sweep of imagination that each of these objects brings to the child, though seldom to the specialized teacher. But even more the non-scientific teacher and the unscientific parent can learn from Miss Stevens the fascination of nature and the beauty of concept and natural law which are inherent in these familiar objects. Surely parents of young children should read Miss Stevens and all those who have not learned from Shakespeare to:

> Find tongues in trees, books in the running brooks,
> Sermons in stones, and good in everything.

GERALD WENDT

[1] *How Miracles Abound.* Bertha Stevens. Illustrated. 200 pp. $2.50. 1941. John Day.

WILLIAM JAMES, 1842–1910

THE PROGRESS OF SCIENCE

WILLIAM JAMES, 1842–1910

It is the fortune of some thinkers to modify so radically the color of their intellectual environment that many of their hardest-won ideas appear like commonplaces to succeeding generations. In many respects this has been the fate of William James, the centenary of whose birth is being celebrated this year. It is true that not all the positions for which he fought in psychology and philosophy have become widely accepted; nor did he leave behind him a sizable following of disciples who subscribed to the essential details of his thought. But the larger features of his work—its voluntaristic naturalism and empiricism, its distrust of dogmatic claims to final truth, whether in science, philosophy or religion, and its emphasis upon the novelties and contingencies which characterize the operations of nature—have been intimately absorbed into our own modes of thought; we can appreciate the innovations they represented only by contrasting the quality of our own intellectual atmosphere with that of James's generation.

James's most distinguished and substantial contributions were made to psychology. He came to the subject when the dominant point of view was an atomistic associationalism colored by remnants of the classical faculty psychology, and when instruction in it in this country was ancillary to buttressing religious and moral dogmas against the encroachments of natural science. James was rapidly convinced of the sterility of the customary introspective analyses, became impressed by the work of Helmholtz and Wundt in physiological and experimental psychology, and early in his career desired for psychology the status of a natural science. He was the first to teach physiological psychology in the United States, and stimulated the establishment of psychological laboratories in various parts of the country; but he never regarded psychology as simply a branch of physiology, his own experimental work was relatively insignificant, and in the end he came to distrust "brass instrument" psychology as a blind alley which would never lead to the achievement of an integral and illuminating science of man. What James envisaged was a psychology assimilated to biology, which would exhibit man's place in nature and explain mental phenomena in genuinely causal terms, and which would thus provide, among other things, the instruments for controlling various mental disorders. He was conscious that this ideal was far from being realized, and upon completing his "Principles of Psychology" (in 1890) he remarked that "psychology is like physics before Galileo's time—not a single *elementary* law yet caught a glimpse of." Nevertheless, his great treatise blazed a path in the desired direction, even though it retained some of the preconceptions of subjectivistic psychology. It adopted the Darwinian idea of the mind as an instrument in the body's evolutionary interaction with the environment; it rejected, accordingly, the Spencerian conception of the mind as the passive recipient of external stimuli, and argued for its intermediary, teleological function with respect to the overt action of the body. It dismissed as gratuitous the introduction of substantial, non-empirical agents (such as the "transcendental ego") to account for the obvious unity of mental life; and it attempted to explain this unity both in terms of the mechanism of organic behavior and in terms of the cumulative continuity of the stream of direct experience. James thus directed psychology toward the study of the activities and experiences of the entire organism functioning in an environment, and away from its traditionally exclusive concern with atomized, isolated and subjective contents of a disembodied mind. Although he never quite transcended in a coherent and unambiguous way his ini-

tially postulated dualism between states of mind as psychic existences on the one hand and the objective order of physico-biological mechanisms on the other—indeed, he came to accept a form of the interaction theory of their relation—James laid the foundations for a behavioristic functionalism in psychology, and anticipated important features of other contemporary movements in psychology as well.

While James's intense preoccupation with a considered philosophic outlook upon things is exhibited on almost every page of his explicitly psychological writings, he never achieved a comprehensive philosophy comparable in its sweep and coherence with his treatise on psychology. His numerous books and essays on philosophical themes are fragmentary and suggestive preludes to the systematic work he planned to write but did not live to begin, and the pluralistic pantheism at which he finally arrived was never more than sketched out by him. James's concern with metaphysics was rooted in his profoundly personal religious needs and in his desire to find a cosmic ground for significant moral endeavor. But whatever their psychological sources, his philosophical essays were fructified and served as instruments of clarification by his unusually sensitive recognition of the irreducible variety, the precarious stability and the unique individuality of existential affairs. In spite of his tender concern for the moral values of mystic religious experiences and his espousal of theism, James stimulated the development of a biological, empirical naturalism—a naturalism comprehensive enough to admit the dynamic primacy of men's wills and desires, but also sufficiently responsive to empirical findings not to accept at their face value the claims of the dominant institutional and philosophic religious systems. He thus noted the function of religious beliefs in the context of adjustment to the inclusive environment, while at the same time he regarded as pretentious shams the alleged demonstrations of religious truths which were advanced by the philosophies current in his day. He could find no warrant, either in experience or logic, for the conception of the universe as something integrated by necessary bonds and headed inevitably toward a fixed goal; but he could nevertheless define the conditions under which, in the interests of successful living, it is justifiable to embrace beliefs even when, as frequently happens in matters of vital issue, warranted knowledge is not available.

James's most distinctive contributions to philosophy are consequences of his vigorous individualism and pluralism. He championed pragmatism as a method for determining the significance of concepts in terms of their consequences for individual experience and practice and as a device for permitting the breezes of fresh experience to revivify ancient issues. In his application of the pragmatic maxim to the perennial problem of the nature of truth, for example, he underscored the instrumental rather than the reproductive character of thought, and he made evident the empirical and natural foundations of human knowledge. He found the notion of a monistic determinism, whether in physical nature or in human history, to be incongruous with the patent variety of existential determinations and with the actual role played by individuals in dynamic transactions; and while he had no systematic social philosophy, he was an individualistic liberal in his evaluation of contemporary affairs and maintained that moral activity would lack significance if individual intervention in natural processes made no difference in their eventual outcome. James was impressed by the magnitude or our ignorance and distrusted the authoritarianism of institutionalized science as well as religion. He was therefore unusually and perhaps even quixotically tolerant toward heterodoxy, and championed causes held in disrepute by the established professors of science. His

defense of psychical research, for example, was motivated as much by his opposition to the dogmatic apriorism which dismissed allegedly psychic phenomena as spurious without a proper examination, as by his conviction that something significant lay beneath the quackery of spiritualistic séances. James was undoubtedly hasty, impatient and incautious in much of his philosophizing, and his frequently ill-considered formulations led to serious misunderstandings and to irrational disavowals of the tools of critical intelligence. But because he communicated the freshness which comes from sailing courageously on the unfathomable ocean of experience, he brought relief from the stuffy dogmatisms of less-traveled folk and helped introduce new standards of intellectual forthrightness and honesty. Of James it may be said what he said of another: he was the knight-errant of the intellectual life.

ERNEST NAGEL

AWARD OF THE CHEMICAL INDUSTRY MEDAL FOR 1942 TO DR. HARRISON E. HOWE

HARRISON ESTILL HOWE, honored by the award of the Chemical Industry Medal for 1942, has for a score of years guided the destiny of *Industrial and*

Harris and Ewing

DR. HARRISON E. HOWE

Engineering Chemistry through a period of enormous fecundity of industrial research. The medal—given annually "to a person making a valuable application of chemical research" by the Society of Chemical Industry—will be presented to Dr. Howe on November 6. His function has been that of guide, philosopher and friend to industry on the one hand and to research on the other. To each he has interpreted the other in a way to foster mutual confidence and cooperation.

Editors generally content themselves with the printed word alone as their medium of expression and make for themselves a kind of secluded cloister behind their pages. That could never content Dr. Howe. His boundless humanity has required personal contacts, multitudes of them, to give it scope. Thus one finds him a member by appointment, *ex officio* or by special invitation of committees by the score. These duties for and to applied chemistry are so much a part of the man that he is constantly taking on new commissions. In all, his vigorous imagination, his kindly humanity and his huge capacity for work have combined to make him one of the best-loved and most respected figures in American chemistry to-day.

Primarily Dr. Howe's activities have been connected with the American Chemical Society, to which he has given much. But the National Research Council, Science Service and the Chemical Warfare Service too have drawn heavily upon him, as have many, many others.

As if his activities in and for chemistry and research were not enough, Dr. Howe has maintained as an active avocation a prominent and busy place in Rotary International. Always he is busy and always occupied with people.

Yet in spite of his outstanding collection of activities of many kinds (which he calls "goat feathers"), Dr. Howe seldom appears to hurry, never bustles, and always has time to do a good turn for any one who needs his help.

Summing up a career of such catholicity of interest and accomplishment is a task of major magnitude. Indeed, it is quite impossible to stop its progress long enough to get more than fleeting glimpses of its many ramifications. Clearly the outstanding achievements of the man and editor are to be found in the extraordinary development of the publications under his care. *Industrial and Engineering Chemistry* has grown to occupy under his guidance an outstanding place in the research literature of the world. It has been split into three principal parts, Industrial and Analytical Editions and *Chemical and Engineering News*, each of which is an outstanding publication in its own right and field. The American Chemical Society News Service has, under Dr. Howe's supervision, become a recognized agency for the general dissemination of news about chemistry and chemical industry to the public at large. The Technological Series of American Chemical Society Monographs has been built by him into a vital and growing library of chemical technology.

Any of these major achievements would merit recognition by a medal. The combination of these and innumerable lesser accomplishments by one man richly deserves the highest accolade.

D. H. KILLEFFER

CONTROL OF DESTRUCTIVE INSECTS BY AIRCRAFT

IN the production and storage of food during times of peace certain practices and methods are used to reduce the larger losses caused by insect pests, while many of the smaller ones are not seriously regarded by the producer and dealer. When the more serious insect pests, such as grasshoppers, threaten the destruction of crops over large areas, organized and well-directed campaigns are required for their control. The gradual adaptation of such combat methods and the use of airplanes by the Bureau of Entomology and Plant Quar-

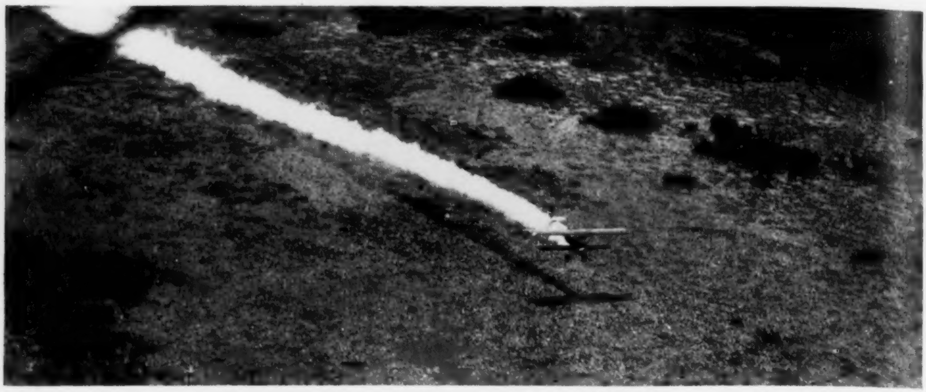
LOADING THE HOPPER OF A PLANE WITH BAIT

antine over a number of years have demonstrated that airplanes do effectively serve in reconnaissance for the pests, as well as for wholesale destruction of the insect invaders through applications of poisoned dusts and baits.

As early as 1919 airplanes were used, under the direction of W. D. Hunter, for locating fields of cotton in the areas recently infested by the pink bollworm and mosquito breeding areas that were otherwise concealed from view by wooded and swamp lands. These surveys were followed by use of aircraft in dusting wooded areas for the catalpa sphinx in 1921; by development of methods for dusting fields of cotton with calcium arsenate at Tallulah, Louisiana, for control of the boll weevil in 1922; and to a limited extent for applying paris green to the swampy breeding places of malaria-carrying mosquitoes. Control of mosquitoes by airplane was accomplished in Louisiana and South Carolina about twenty years ago, and recently the Tennessee Valley Authority applied 100,000 pounds of paris green to breeding places under its control. An oil and a liquid pyrethrum larvicide were also effectively applied to mosquito-infested marshes in New Jersey, but airplanes have not yet been used extensively in applying liquid sprays. It is likely that a reduction of weight load through the use of concentrated sprays may facilitate airplane use on mosquito-control projects.

An experimental airplane dusting of cotton at Tallulah with calcium arsenate in 1922 for the control of boll weevils resulted in an increase of 750 pounds of seed cotton per acre. It was estimated that a single plane manned by a pilot and two mechanics was capable of doing the work of 1,500 to 2,000 men with hand dusters on the ground. There was also a saving in the time required for applications when the fields were too muddy for operation of ground machines. By 1941 about 200 airplanes were engaged in dusting cotton and other crops, and during the year approximately $1\frac{1}{2}$ million acres of cotton and several hundred thousand acres of vegetables were treated in this manner. Airplanes have also been used for seeding range lands and rice and for applying fertilizers. Owing to the need for trained pilots in military services, there has been some reduction in crop dusting.

In 1939 commercial airplanes applied 2,609 tons of poisoned bran and sawdust bait to a total of about 260,000 acres of land in Montana for the control of grasshoppers. The applications were made after flights of the

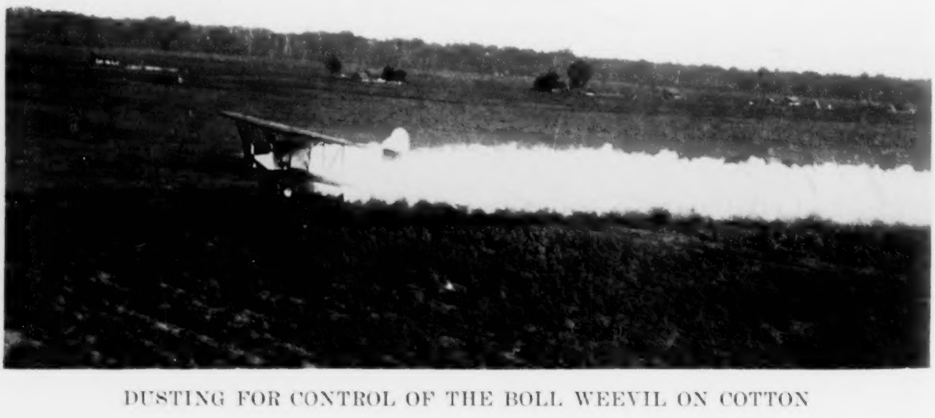


DUSTING SHALLOW WATER FOR CONTROL OF MALARIA MOSQUITOES

lesser migratory grasshopper (*Melanoplus mexicanus mexicanus* (Sauss.)) to locations for resting and feeding upon growing crops were observed from airplanes. When the grasshoppers settled in new places, it was necessary to truck supplies of bait from mixing stations to improvised landing fields and to service the planes as rapidly as possible. The cost for mixing, handling and spreading the bait by airplane averaged $23.57 per ton, or about 24 cents per acre. Since this work was accomplished primarily in restricted areas where the adult hoppers were concentrated, the baiting protected the growing crops by poisoning the hoppers. Because the poisoning occurred before egg laying took place, the baiting also reduced infestations for the following year.

Another migratory grasshopper, *Dissosteira longipennis* (Thos.), which occurs in the southern portion of the Great Plains, has the habit of congregating for the purpose of laying eggs. From an airplane it was possible to detect the egg beds and to apply the poison baits effectively to these concentrations. It is estimated that about 90 per cent. of the adult populations of this species were poisoned in this manner, a considerable portion of the work being accomplished in rugged terrain that was not accessible by any other means.

In the Northwest, where Mormon crickets are a serious problem, the timely use of hand and power machinery



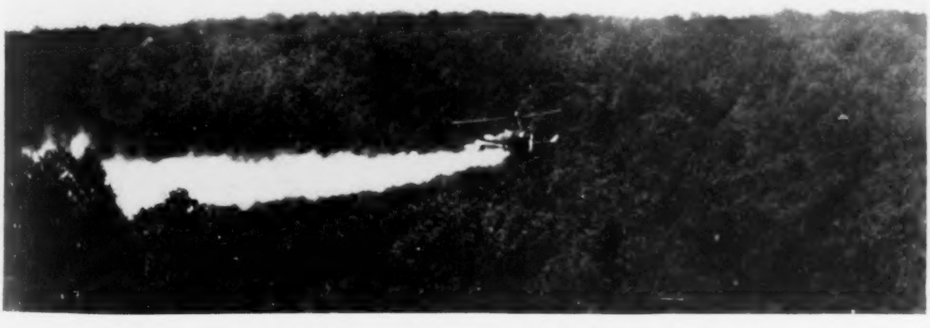
DUSTING FOR CONTROL OF THE BOLL WEEVIL ON COTTON

DUSTING FOR CONTROL OF THE WHITE-FRINGED BEETLE

for baiting and dusting crickets was effective in protecting crops. These methods did not prevent migrations of crickets each year from the higher elevations, and the uncontrolled areas in the mountains were too rugged for ground distribution. There was a distinct need for the control of newly hatched crickets in the early spring at or near the egg beds to prevent the formation of migrating bands which might invade the valleys and crop lands. In 1941 aircraft was successively used in locating these concentrations of crickets and destroying them by applying poisoned bait before they invaded the lowlands. The use of airplanes over much of the area reduced the costs to an average of 59 cents per acre as compared with $2.15 for the ground methods employed in 1938. The average cost per acre baited by airplane was 29.97 cents in 1941.

In baiting grasshoppers in the vicinity of crops in 1941, airplanes treated on an average 1,633 acres each day, while a ground crew operating a mechanical spreader averaged 91 acres. In other words, 1 airplane with a crew of 4 men accomplished as much work as 18 trucks and bait spreaders with a crew of 36 men, and since the purchase price of the spreaders and trucks amounted to about the same as that of the plane, there was no additional investment for equipment.

In 1942 more than two square miles of gypsy moth-infested woodlands in a rugged portion of Connecticut were treated by applying lead arsenate and fish oil in



AUTOGIRO DUSTING WOODLAND FOR INFESTATION OF THE GYPSY MOTH

a dual jet from an autogiro. The cost of such treatment was materially less than would have been involved in the use of standard types of apparatus. The success obtained with this method gives promise that it may be found satisfactory for combating various other pests.

The use of airplanes for scouting, dusting and baiting for control of destructive insects may now be considered an important factor in the protection of food and fiber crops by averting the losses caused by insects, and by distinctly conserving manpower for the big job of winning the war and feeding the hungry.

W. E. Dove

THE SUMMER CONFERENCE ON SPECTROSCOPY AND ITS APPLICATIONS

A tenth Summer Conference on Spectroscopy and Its Applications was held at the Massachusetts Institute of Technology on July 20 to 22, 1942, under the joint auspices of the Optical Society of America and the Institute.

In view of the difficulties of transportation during the emergency, and the fact that most spectrographic analysts are heavily occupied with war work, it had been considered doubtful whether the usual conference should be held this summer. In order to determine the probable attendance and the number of papers likely to be presented at such a conference, postcard ballots had been sent out early in the year. The response to these indicated that a conference would be well attended if held. The attendance turned out to be 302, an excellent growth from the 65 who had registered at the first conference in 1933. That the conference was so well attended is probably due to the fact that spectrographic methods of analysis are of increased importance now in many war industries.

In his welcoming remarks, the chairman took the occasion to sum up the progress in spectrographic analysis which had been made during the preceding decade, as indicated by a detailed analysis of the categories of paper presented at the ten conferences.

Probably the most important trend noted was the increase in interest in the application of spectrographic methods to problems of chemical and metallurgical analysis in industry. Of the three hundred papers which had been presented at the ten conferences, most in the early sessions dealt with pure spectroscopy or with applications of spectroscopy to biology, whereas in later years the emphasis was on applications in metallurgy and to industry in general. The tabular analysis showed: Papers dealing with emission analysis—64; with absorption spectro-photometry—28; with improvements in the techniques of photography—9. Forty papers were concerned primarily with the improvement of spectrographic apparatus. The remaining papers dealt with applications of spectroscopy to various scientific fields—8 were concerned with astronomy, 68 with biology, 25 with chemistry, 26 with metallurgy and 33 with physics.

Of especial interest was the increased use of diffraction gratings, particularly in industrial laboratories. At the first conference the statement that grating spectrographs should be found useful in industry had been greeted with much skepticism. At the tenth, two manufacturers presented descriptions of new commercial grating spectrographs constructed on the Wadsworth principle.

Notable also was the increase in the precision of spectrographic methods of qualitative analysis which ten years have brought about. At the first conference the results obtained by emission analytical methods could be expected usually to be correct to within ± 10 per

cent. of the concentration of material or, in exceptional cases where great care was taken, ± 5 per cent. Even this degree of precision was worthwhile, since by spectrographic methods it was possible to determine minute concentrations of impurities in a sample without the bother of chemical preparation. By 1942, however, precision had been increased so much that routine analyses are being carried out with a precision of ± 3 per cent., and several workers reported results at the conference which showed an internal consistency and check with carefully prepared standards to within ± 0.7 per cent. of the amount of material present, whether 5 per cent. or 0.0005 per cent. These results are to be compared with results obtained with ordinary wet chemical methods of analysis which are likely to be precise within ± 2 per cent. for concentrations of 1 per cent. or greater when a sufficiently large sample is available, and to errors as great as 100 per cent. when concentrations are still a thousand times the minimum detectable with the spectrograph.

The tenor of the introduction by the chairman was carried on by Dr. W. F. Meggers, of the National Bureau of Standards, who spoke on "Ten Years' Progress in Spectro-chemical Analysis," and by Dr. Keivin Burns, of the University of Pittsburgh, who spoke on "Spectroscopy in World War I."

In view of the dual nature of the conference, the arrangement of meetings was somewhat different than that of previous occasions. During the first day and a half 16 papers were given which dealt primarily with spectrographic analysis of materials. On the second afternoon a Symposium on Invited Papers on Fluorescence and Phosphorescence was held. This consisted of four papers, ranging from "The Theory of Luminescent Materials," by Professor F. Seitz, of the University of Pennsylvania, through "Fluorescent and Phosphorescent Lamps," by E. W. Beggs, of the Westinghouse Electric and Manufacturing Company, and "Fluorescent and Phosphorescent Pigments and Coatings," by G. F. A. Stutz, of the New Jersey Zinc Company, to "Cathodoluminescent Materials," by H. W. Leverenz, of the RCA Manufacturing Company.

On the third day regular sessions of The Optical Society of America were held, the papers given in the morning dealing with general problems of optics, while those in the afternoon dealt primarily with spectrographic applications.

At the tenth conference it was apparent that it and its nine predecessors had been held during the period of most rapid growth in the application of spectrographic methods of analysis to problems in all the natural sciences, and in most of the biological, metallurgical and agricultural industries.

George R. Harrison

THE NEW AUDUBON BIRD HALL OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA

After four years of planning and work, the staff of the Academy of Natural Sciences of Philadelphia is being rewarded on October 7 when the new Bird Hall, named for John James Audubon, will be opened with a reception to members. The next day the hall will be open to the public and will be one of the centers of attention when the American Ornithologists' Union convenes in Philadelphia later in the month.

The Bird Hall, situated on the third floor of the academy's building at Nineteenth and the Parkway, replaces a bird hall which was fashioned in the manner of the nineties. In three great sections from which natural light is excluded, the birds of the world are shown in natural

positions against backgrounds representing their habitats. These backgrounds have been painted by Virginia Campbell, the staff artist, under the direction of R. Meyer deSchauensee, curator of birds, and Harold T. Green, curator of exhibits. Frederick Stoll is responsible for the taxidermy.

The same characteristic energy which marked the creation of North American Hall and the erection of twenty habitat groups of large mammals—all by gifts—has resulted in Philadelphia's having a bird hall not only different from any other but adapted to the three functions of the academy—research, popular education and public exhibition; none of the functions has been slighted at the expense of another.

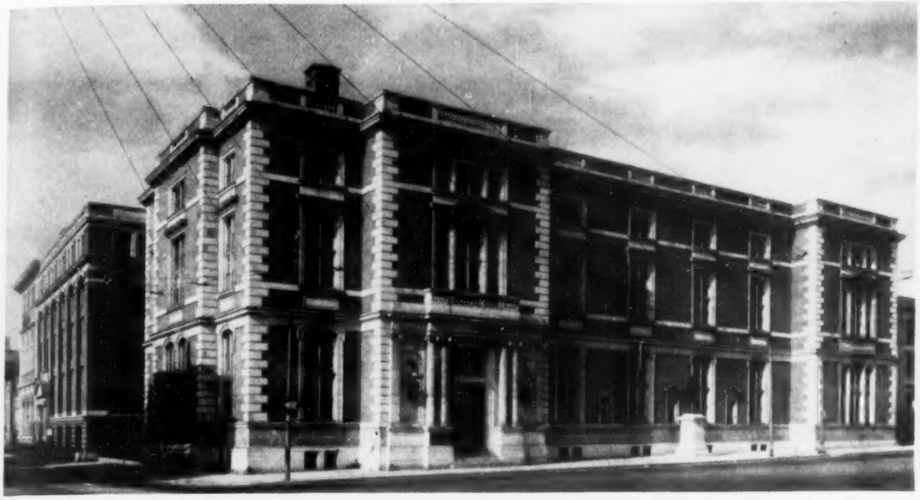
ONE OF THE SECTIONS OF THE AUDUBON HALL
ARTIFICIAL LIGHT IS USED IN THE NEW HALL, ALL NATURAL LIGHT BEING EXCLUDED.

The hall is being opened with only two or three cases incomplete, and it is believed that at the opening the cost of these will be subscribed. No academy income is ever spent for public exhibitions. The institution, 130 years old this year, is supported wholly by gift and from the income of a small endowment. It receives no public funds. Income goes for the support of research in the more than a dozen scientific departments and for scientific publication and the upkeep of the building. Public exhibitions in the museum are the result of special gifts for specific purposes.

The new hall is named for Audubon for various reasons. The great painter of "The Birds of America" lived for a short but important period of his life on Mill Grove Farm, near Philadelphia. It was there that he met, wooed and married Lucy Bakewell, who proved to be such a help to him in his struggles to achieve his artistic destiny.

It was in the academy in 1824, then at 35 Arch Street, that Audubon, having given up trying to make a living as a merchant in Kentucky, showed his water colors that eventually went into the double elephant folio. It was in the academy membership that Audubon found certain valuable benefactors, notably Edward Harris, of Moorestown, New Jersey. It is true that the academy could not undertake to sponsor Audubon's publication and that by reason of this inability he went to London in 1826, where he found the Havells, father and son, who undertook the great task of aquatint engraving. But Audubon had close relations with the academy, its members and its collections, and was enrolled as a corresponding member in 1831. The academy was fourteenth on the list of subscribers to "The Birds of America" and that set of four volumes is now in the academy's library. It will be exhibited at the opening of Audubon Hall.

Audubon Hall is arranged primarily on a geographic plan. The visitor enters



BUILDING OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA
THE NEW AUDUBON HALL IS HOUSED ON THE THIRD FLOOR OF THE ACADEMY BUILDING.

from a lobby which eventually will contain habitat groups of passenger pigeon and whistling swan and which is decorated with murals of extinct species. In the hall proper he finds alcoves representing the continents. He sees for example, the birds of North America, South America, Europe, Asia, Africa, Oceanica and the Arctic regions in order. Then he comes to exhibitions showing the evolution of birds, distribution, migration, nesting, economic relationships to man, and the extinct species, of which the academy owns a notable collection. In a separate room are the birds to be found within fifty miles of the academy.

Close attention has been paid to legi-

AN EXHIBIT OF THE BIRDS OF NORTH AMERICA
IN THE NEW AUDUBON HALL THERE ARE MORE THAN FORTY SUCH CASES ARRANGED IN ALCOVES WITH BACKGROUNDS PAINTED IN NATURAL COLORS.

A MUSEUM PREPARATOR AT WORK
THE LIFE-LIKE MOUNTS HAVE BEEN ASSEMBLED ACCORDING TO THEIR GEOGRAPHIC DISTRIBUTION.

ble, simple labelling, to charts comprehensible to students of various ages, to maps, diagrams and models where such things are needed to tell the complete story. The hall's educational function has been worked out so that the classes from the public and private schools which come to the academy for instruction by the educational department under Charles E. Mohr can have the maximum benefit with the least expenditure of time and energy.

The lay visitor and the professional ornithologist have also been considered, so that the pattern of the four rooms will furnish the greatest satisfaction and—the academy hopes—the least criticism. On the floor below is the academy's library of natural history, with its bird section of books and continuous files of journals in many languages. The academy members and ornithologists therefore will have together in one place the materials for bird study in the most convenient form available.

Color, lighting and the comfort of the museum visitor have all been worked out so that objectionable features of the old-fashioned museum bird hall will be markedly absent. The hall and all parts of the museum are free to the public.

M. H.